TRACER TRANSPORT IN CRYSTAL-FACE STORMS DRIVEN BY METEOROLOGICAL FIELDS FROM MM5

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- O_3 : E. Richard – NOAA/AL
- Radar: T. Rickenbach – UMBC/NASA-GSFC

Introduction

- Chemical tracers measured in C-F will aid in diagnosing transport in the tropopause region and aid in understanding the impact of the tropics on global chemical distributions.

Our project goal: Simulate mesoscale chemical tracer distributions during deep convective events observed during C-F.

These simulations are to aid in explaining the observed upper tropospheric distributions of trace gases and water vapor.

MM5 Features

- Run in cloud-resolving mode – 2-km horizontal resolution over 360 x 360 km domain
- Eta fields from 0000 UT for initial conditions (40-km resolution); boundary conditions from Eta fields updated every 3 hours
- 0000 UT to 1800 UT spin-up; output saved for 1800 UT to 2400 UT every 5 minutes
- 23 layers, top at 50 hPa
- Ice microphysics by Lin/Rutledge/Hobbs; Radiation by Dudhia
- Blackadar boundary layer turbulence, Climatological soil moisture

UMD 3-D Cloud-Scale Chemical Transport Model Features

- Run offline using wind, temperature, and hydrometeor fields from MM5
- Contains Van Leer tracer advection scheme
- Reads 5-min interval MM5 data, which is interpolated to 15-s transport time steps
- Run in passive tracer mode – chemical reactions, wet scavenging, lightning NO production turned off.

CRYSTAL-FACE Case Studies

- **July 3** – WB-57 sampled anvils from cells well west of Miami and a line of cells along south east coast of FL
- **July 21** – WB-57 sampled western and southwestern edges of huge anvil from mesoscale convective system, after focusing on anvils from smaller cells along west coast
- **July 23** – WB-57 sampled anvils from cluster of cells near Lake Okeechobee and from offshore system SW of Everglades City

Tracer Initial Conditions

Intial condition profiles for CO, NO_x, and O_3 constructed from composites of:

-WB-57 ascents and descents in areas undisturbed by recent convection

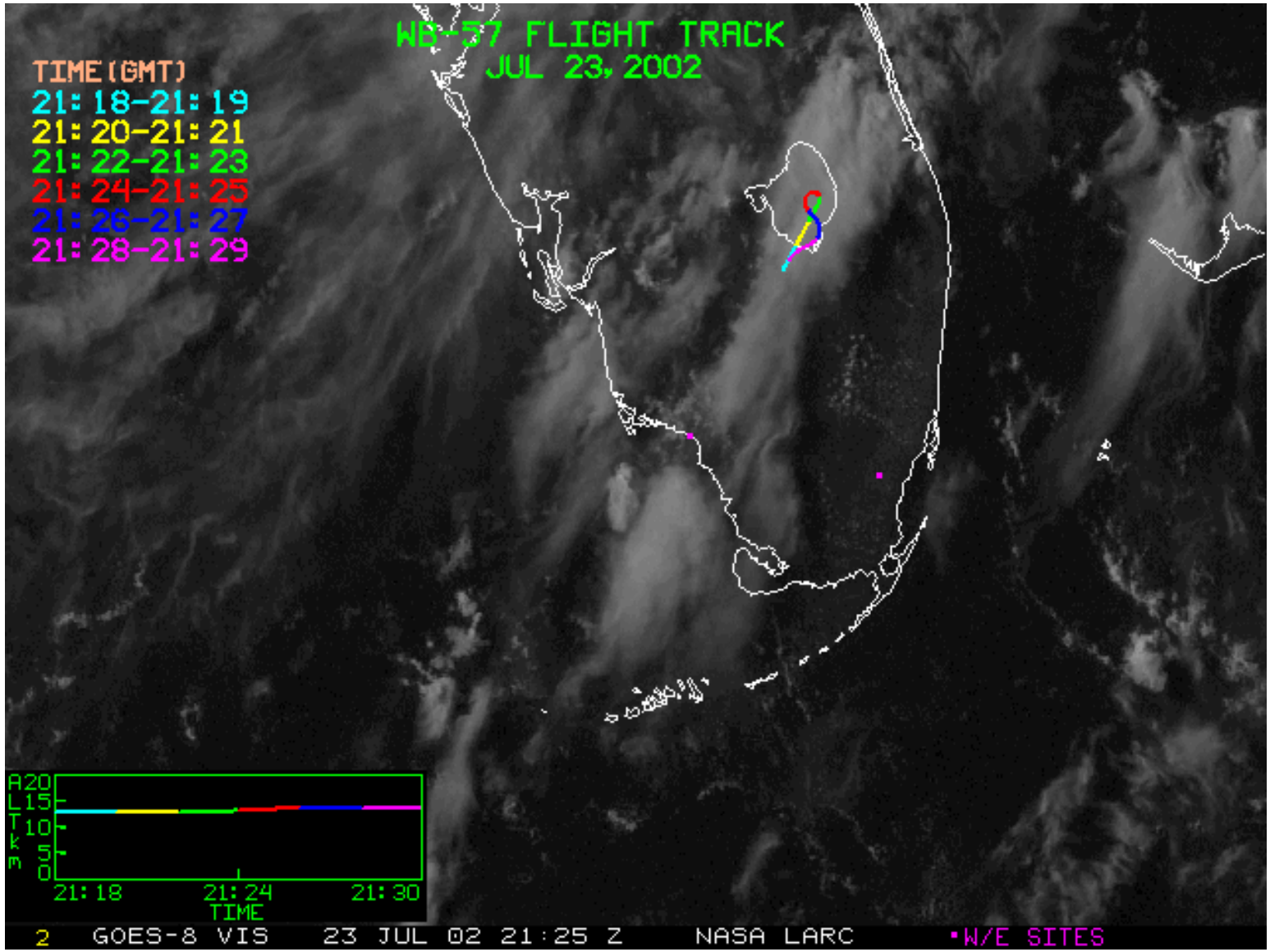
-Surface air quality data from Florida Dept. of Environmental Protection

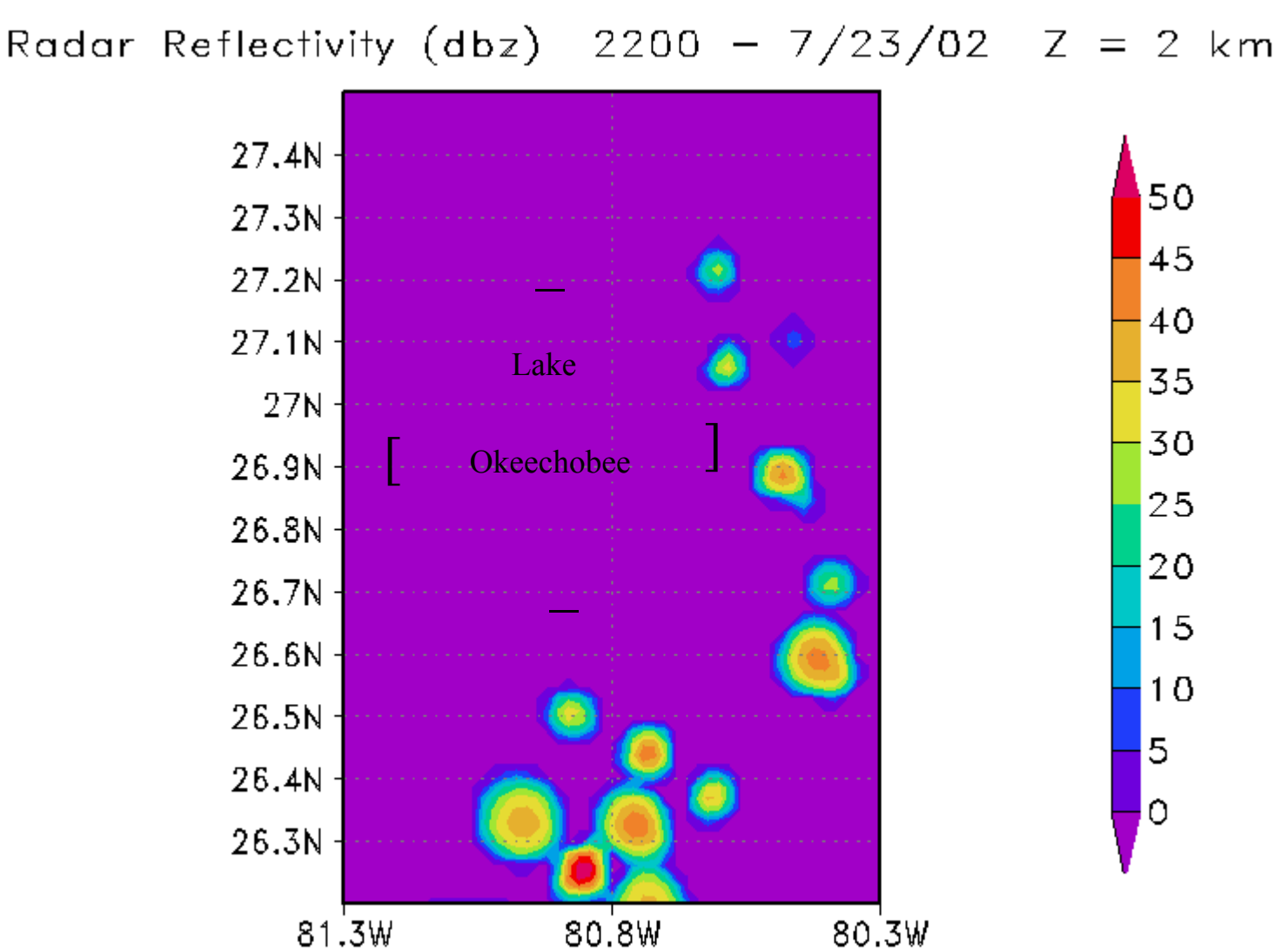
-Output from our 0.5 deg. resolution stretched-grid global UMD-CTM.

NO_x estimated from the photostationary state assumption, using measured NO and O_3 and computed photolysis rates for clear sky.

Procedure

- Simulate storms with cloud-resolving MM5
- Compare cloud characteristics with radar and satellite images
- Develop initial condition tracer profiles
- Simulate tracer transport with offline model
- Map tracer distributions at a variety of levels
- Construct probability distribution functions for model output and measurements in specified regions
- Interpret model and measurements in terms of convective and anvil processes


WB-57 FLIGHT TRACK
JUL 23, 2002
TIME (GMT)
21:18-21:19
21:20-21:21
21:22-21:23
21:24-21:25
21:26-21:27
21:28-21:29
ALT km
20
15
10
5
0
21:18
21:24
21:30
TIME
2 GOES-8 VIS 23 JUL 02 21:25 Z NASA LARC •W/E SITES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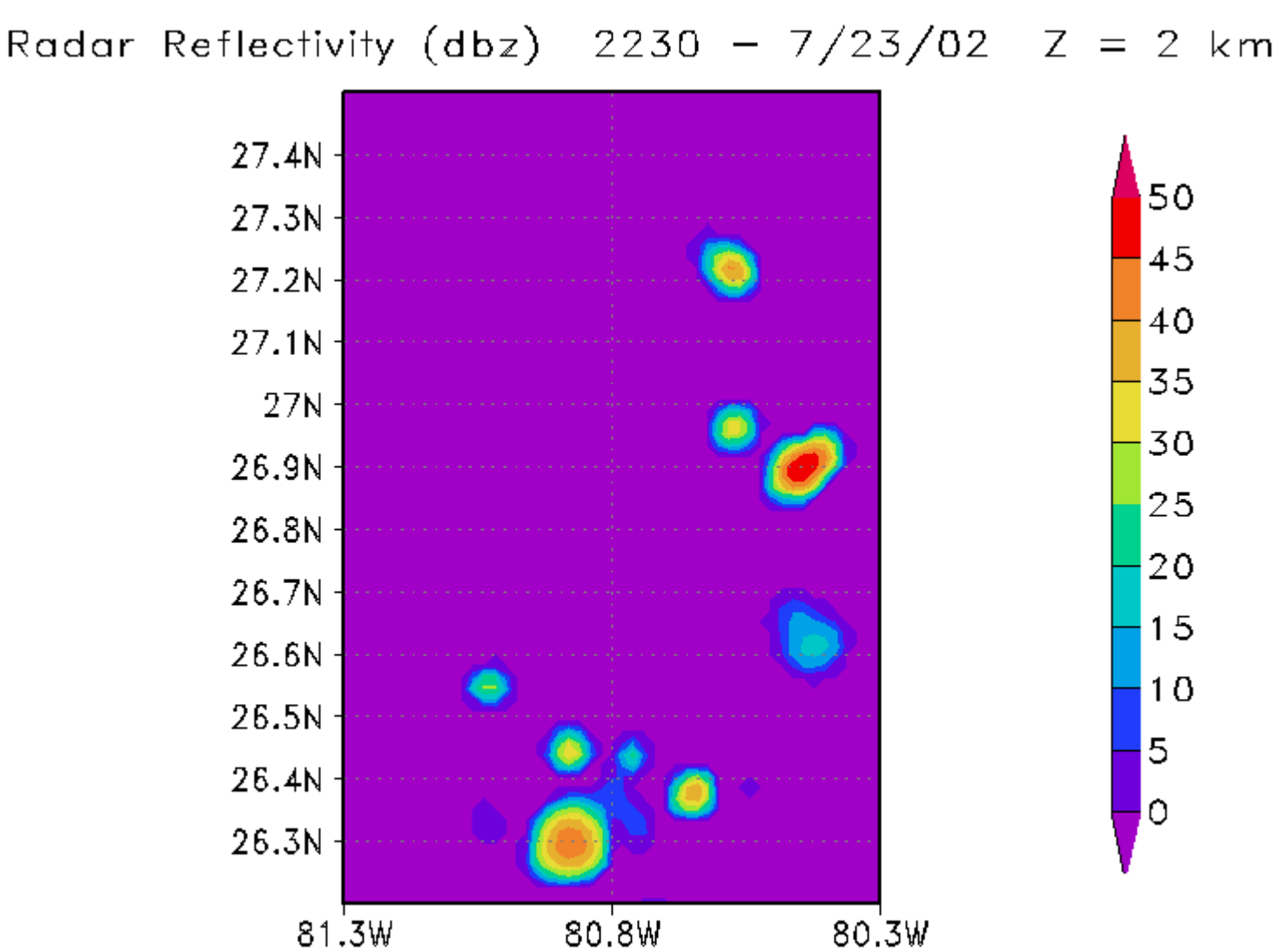
27.3N
27.2N
27.1N
27N
26.9N
26.8N
26.7N
26.6N
26.5N
26.4N
26.3N
81.3W
80.8W
80.3W
Lake
Okeechobee
50
45
40
35
30
25
20
15
10
5
0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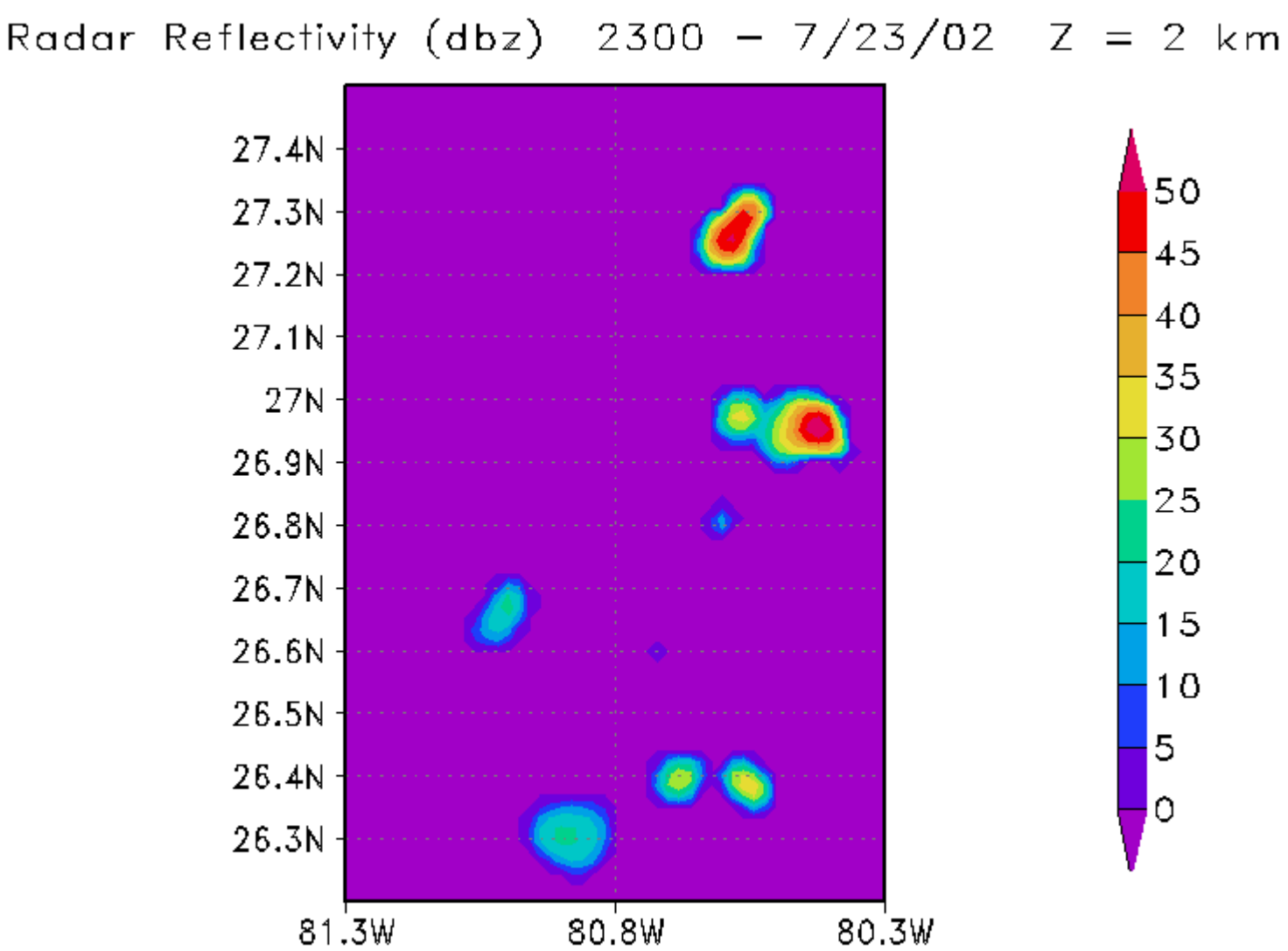
27.2N
27.1N
27N
26.9N
26.8N
26.7N
26.6N
26.5N
26.4N
26.3N
81.3W
80.8W
80.3W
50
45
40
35
30
25
20
15
10
5
0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27N
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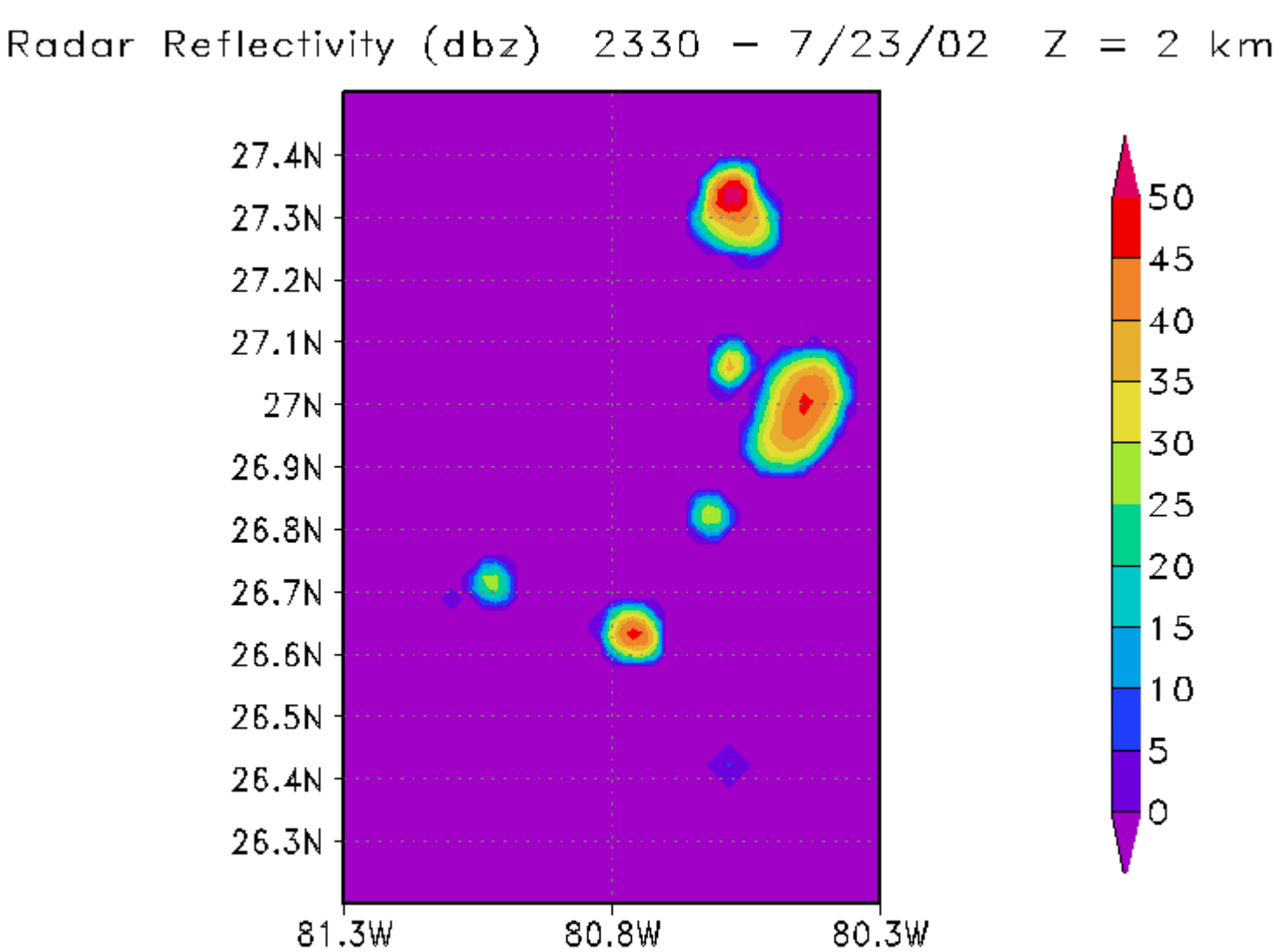
26.6N
26.5N
26.4N
26.3N
81.3W
80.8W
80.3W
50
45
40
35
30
25
20
15
10
5
0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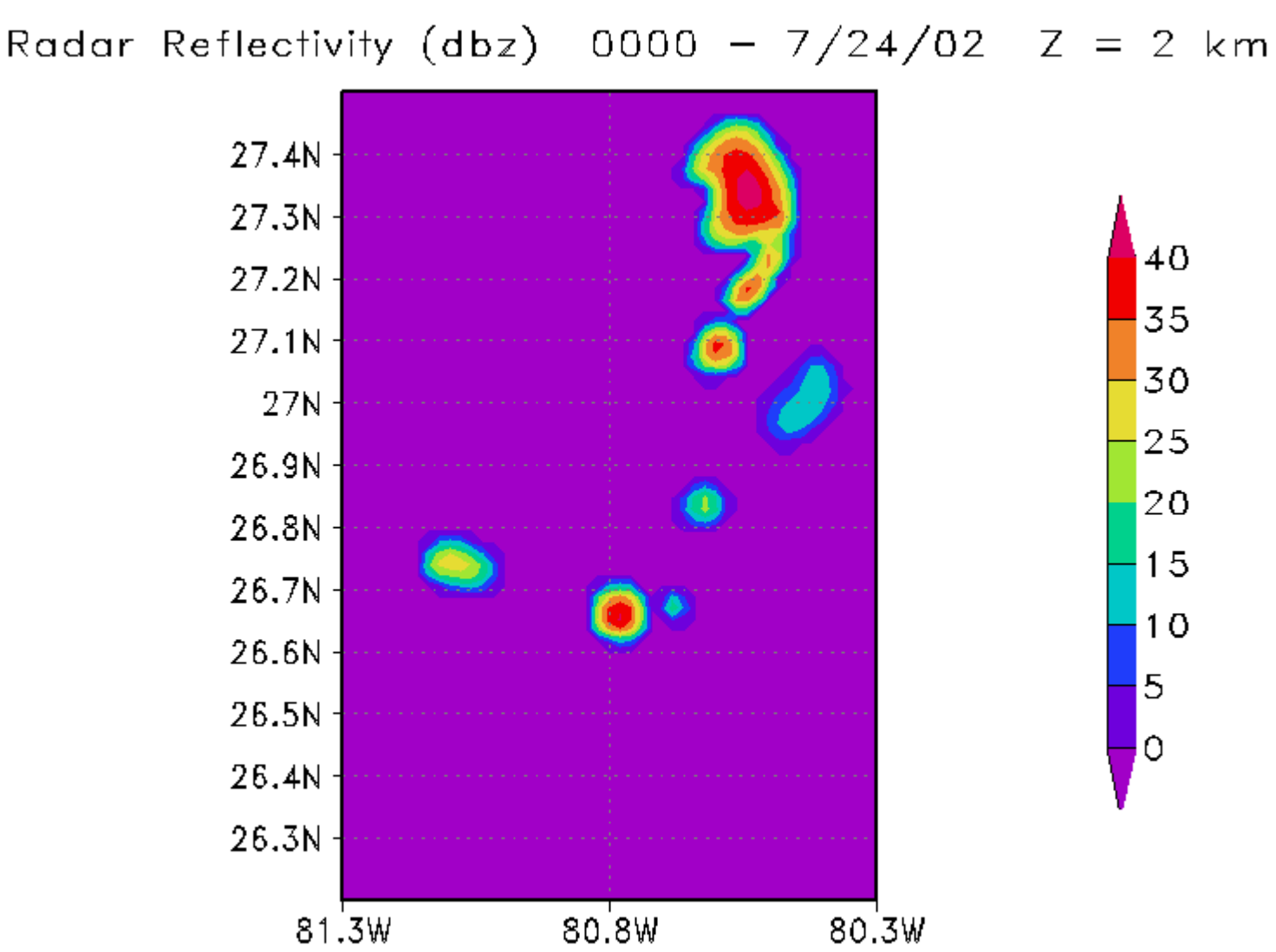
26.7N
26.6N
26.5N
26.4N
26.3N
81.3W
80.8W
80.3W
50
45
40
35
30
25
20
15
10
5
0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27N
26.9N
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26.7N
26.6N
26.5N
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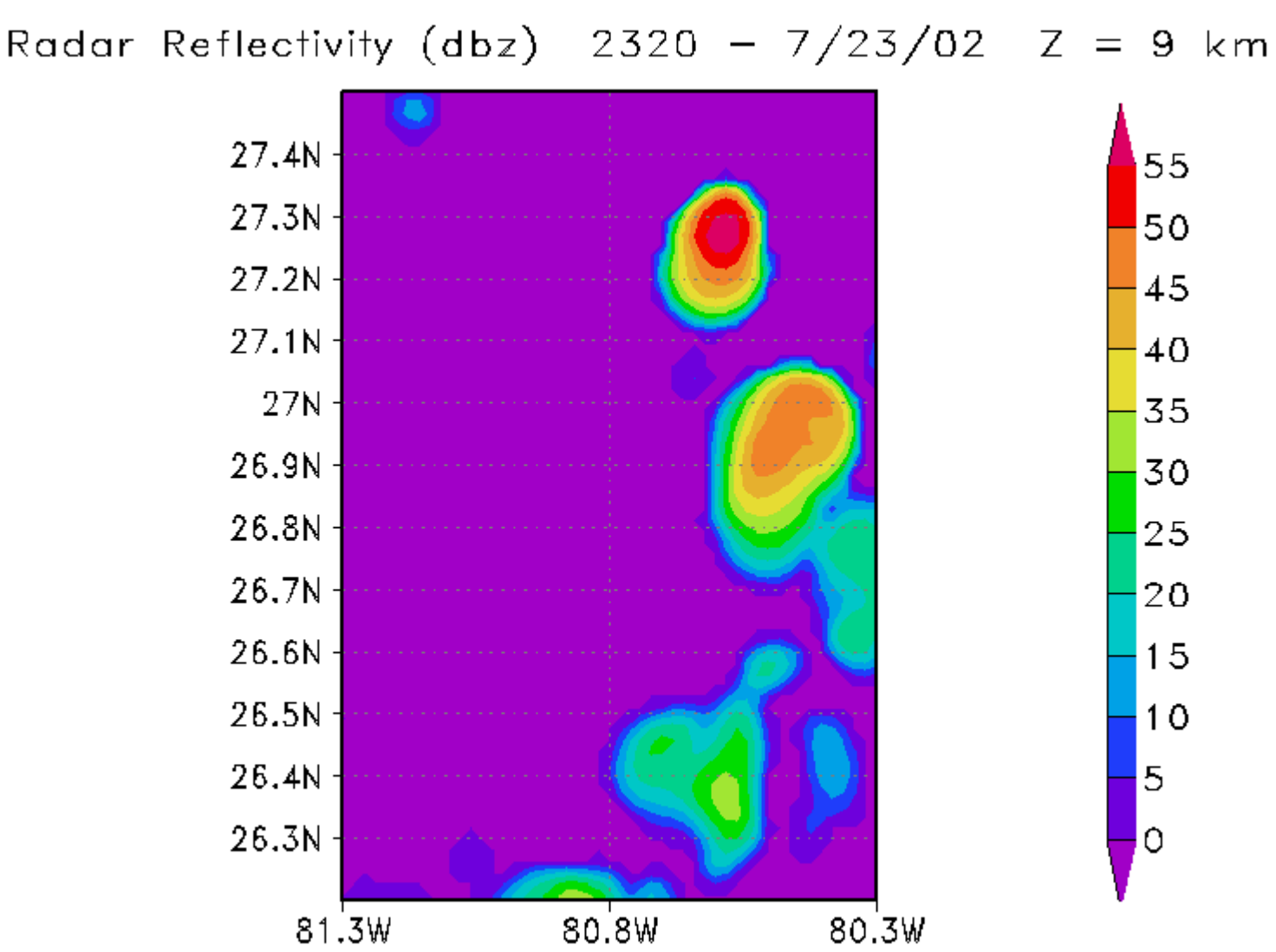
81.3W
80.8W
80.3W
40
35
30
25
20
15
10
5
0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27N
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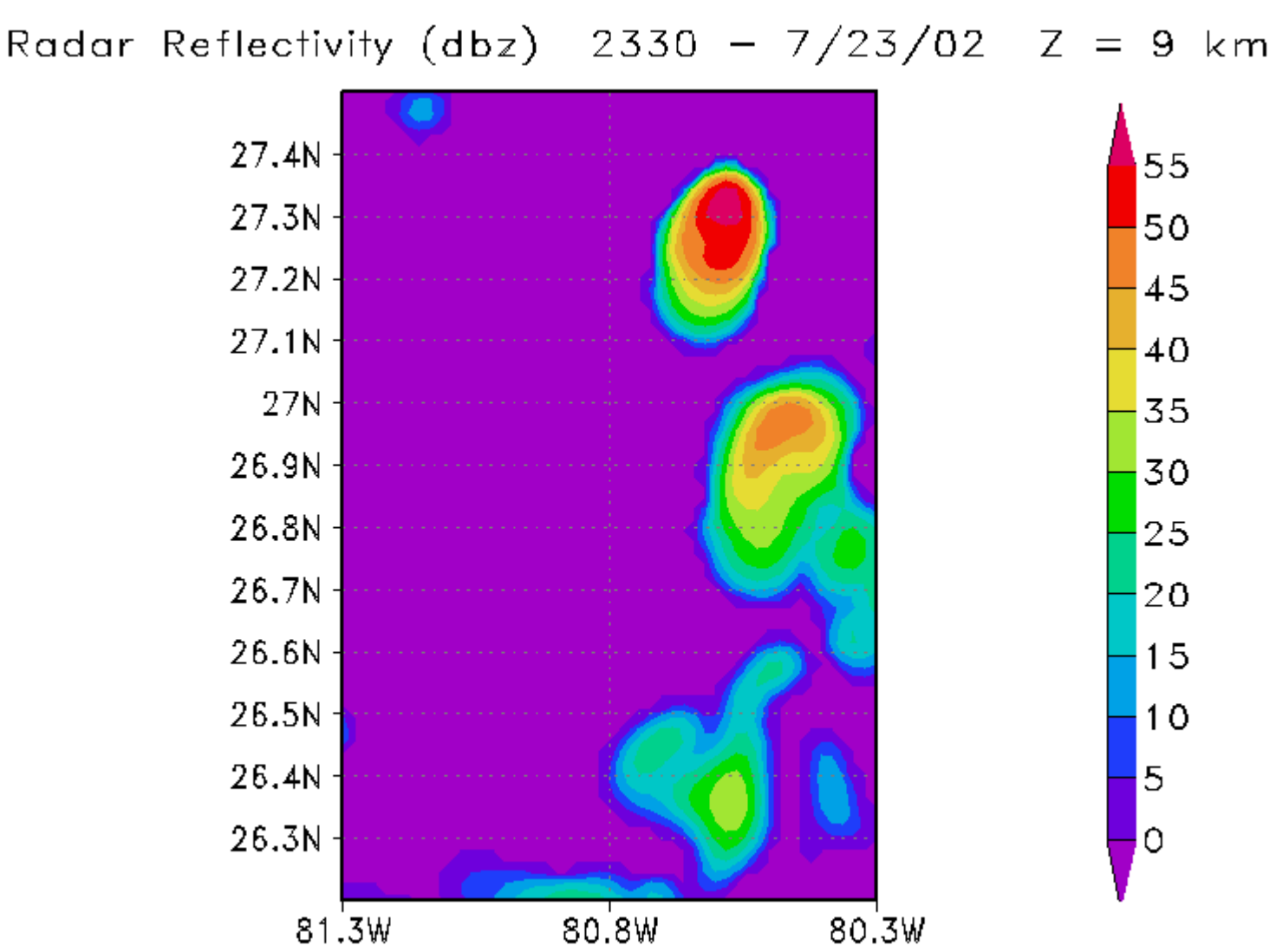
26.7N
26.6N
26.5N
26.4N
26.3N
81.3W
80.8W
80.3W
55
50
45
40
35
30
25
20
15
10
5
0


Radar Reflectivity (dbz) 2330 - 7/23/02 Z = 9 km
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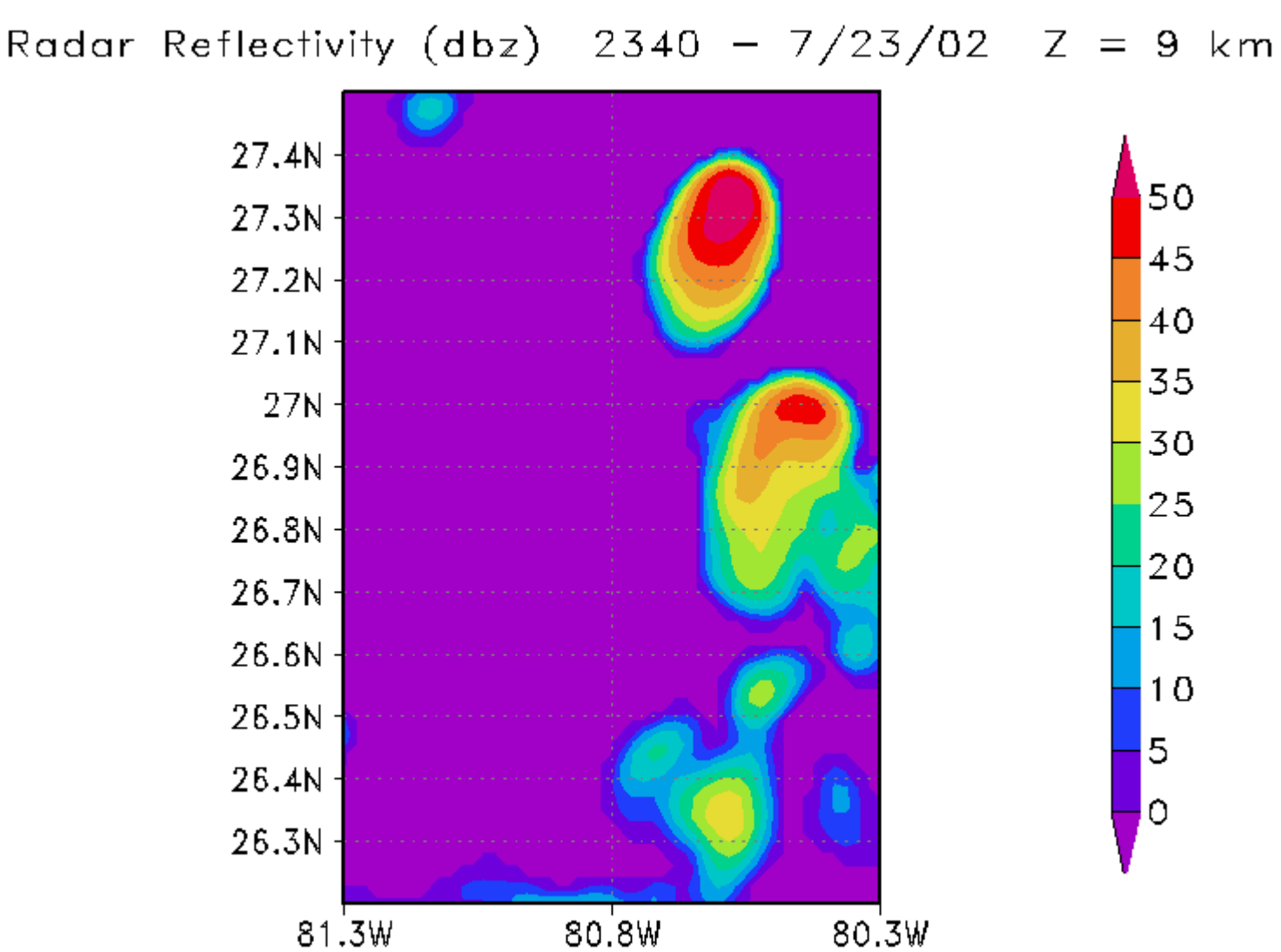
27N
26.9N
26.8N
26.7N
26.6N
26.5N
26.4N
26.3N
81.3W
80.8W
80.3W
55
50
45
40
35
30
25
20
15
10
5
0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27N
26.9N
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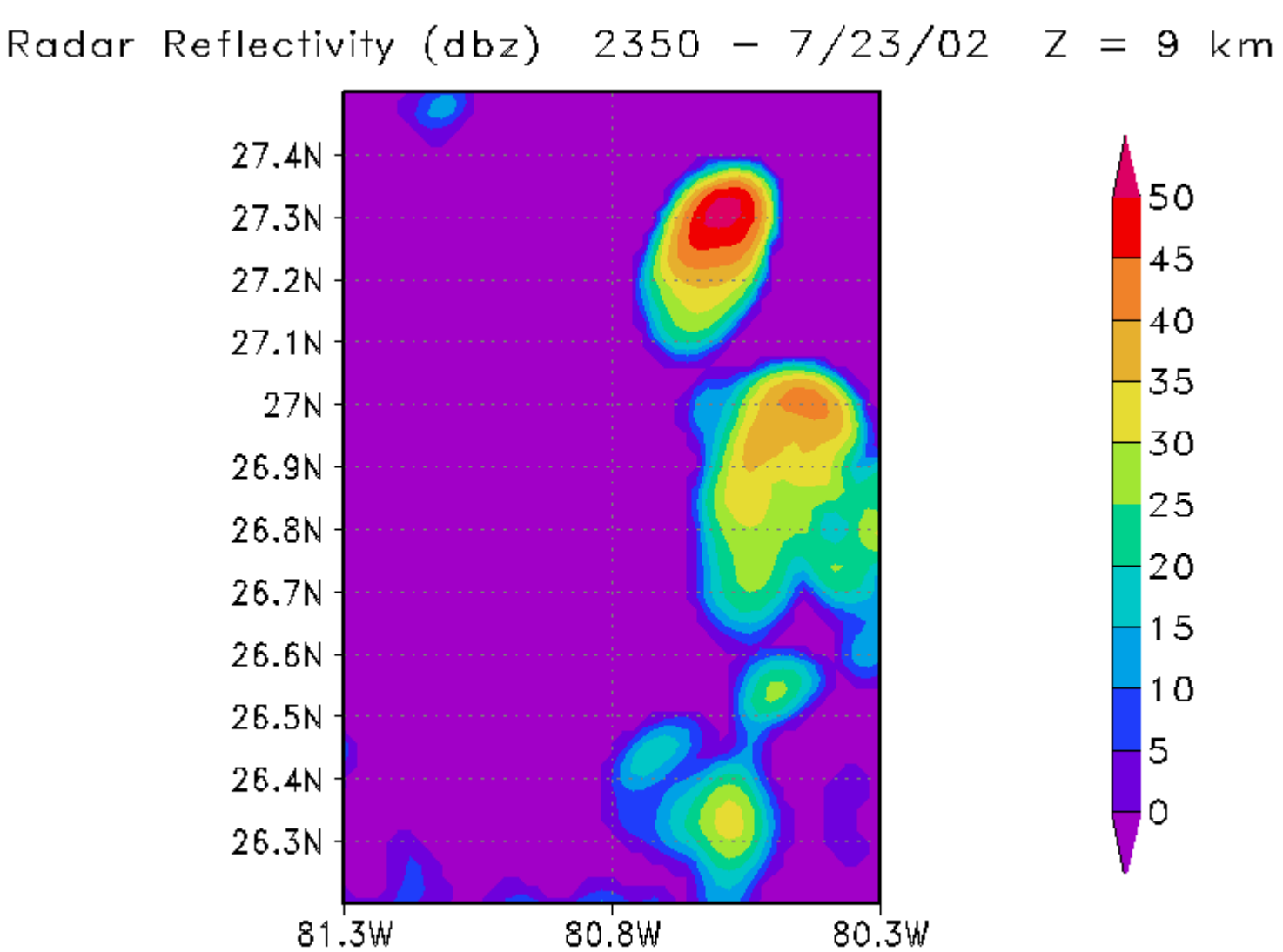
26.7N
26.6N
26.5N
26.4N
26.3N
81.3W
80.8W
80.3W
50
45
40
35
30
25
20
15
10
5
0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27N
26.9N
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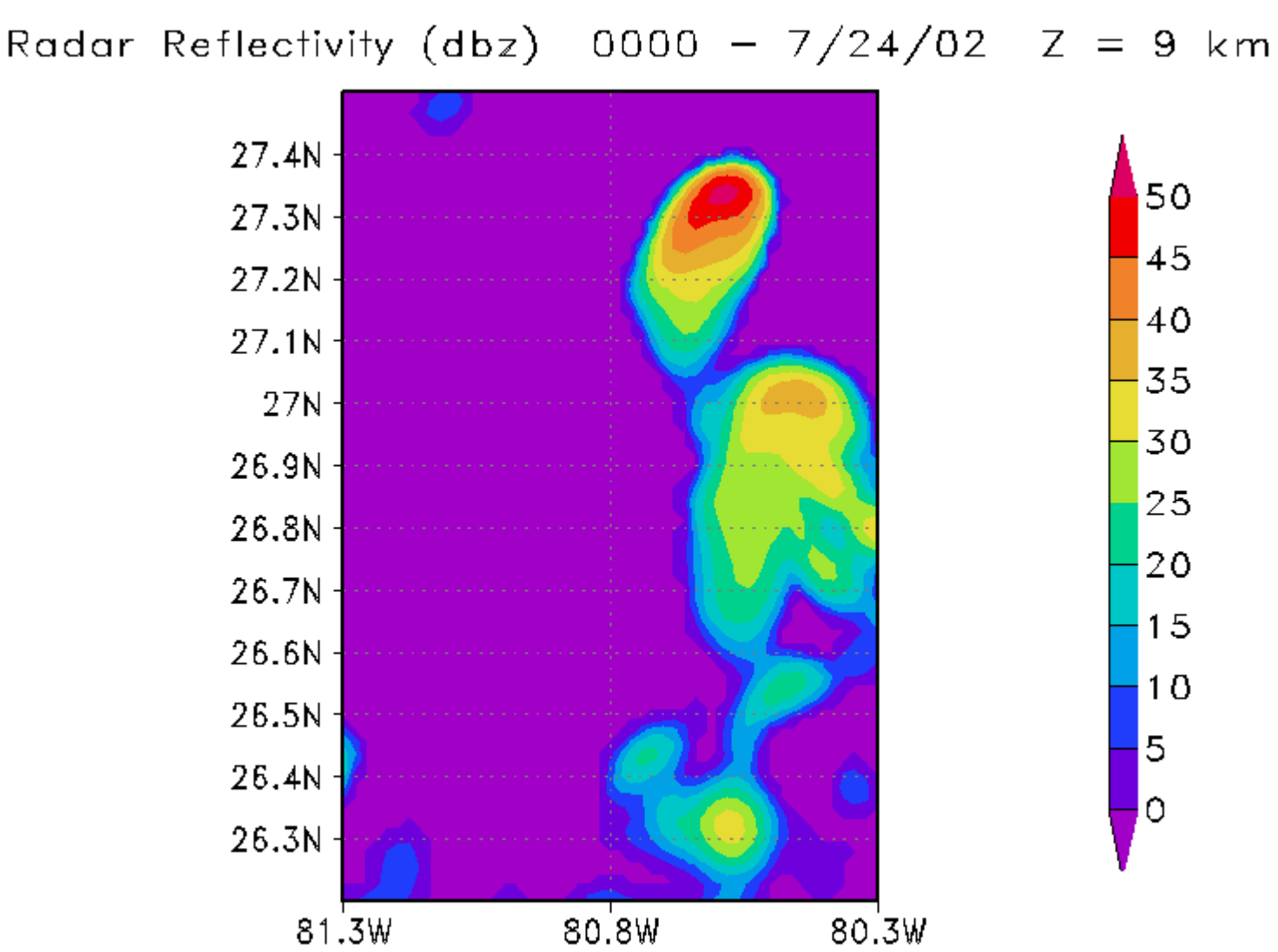
26.7N
26.6N
26.5N
26.4N
26.3N
81.3W
80.8W
80.3W
50
45
40
35
30
25
20
15
10
5
0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27.2N
27.1N
27N
26.9N
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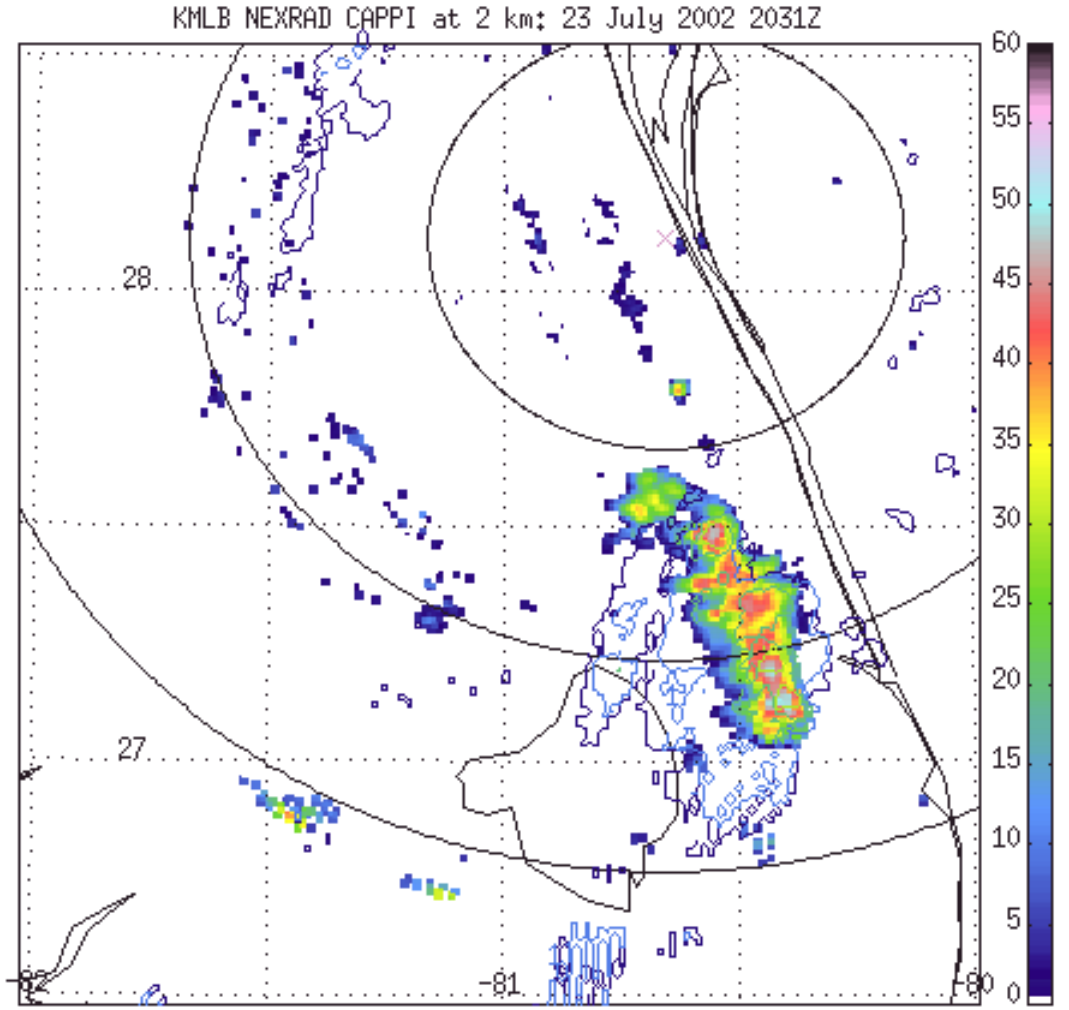
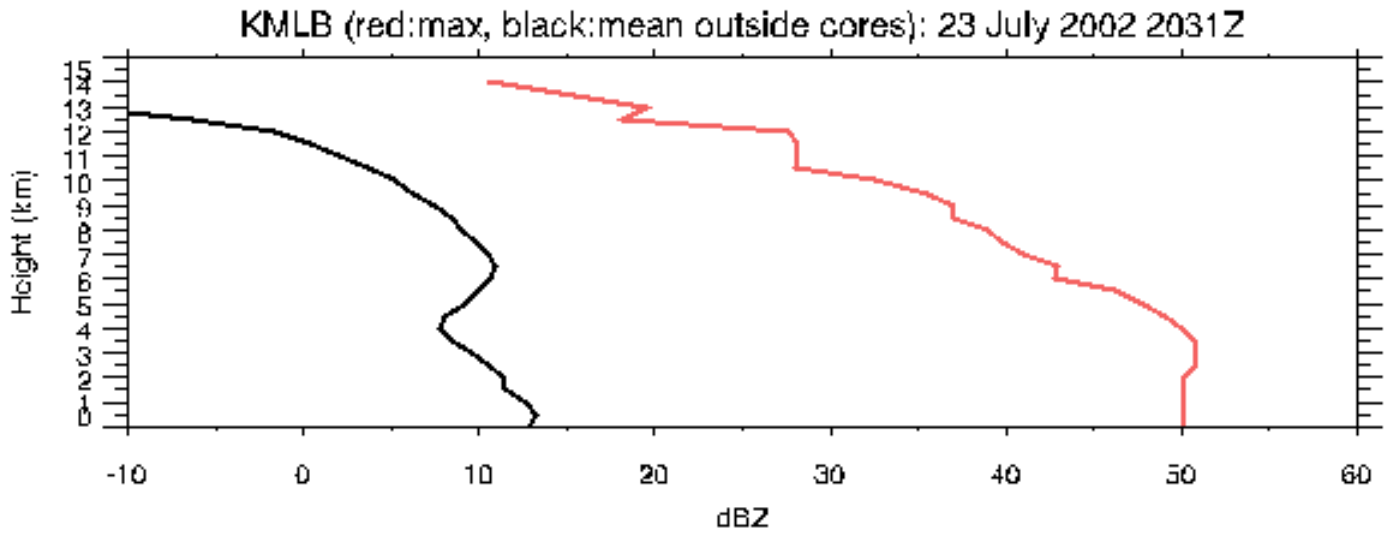
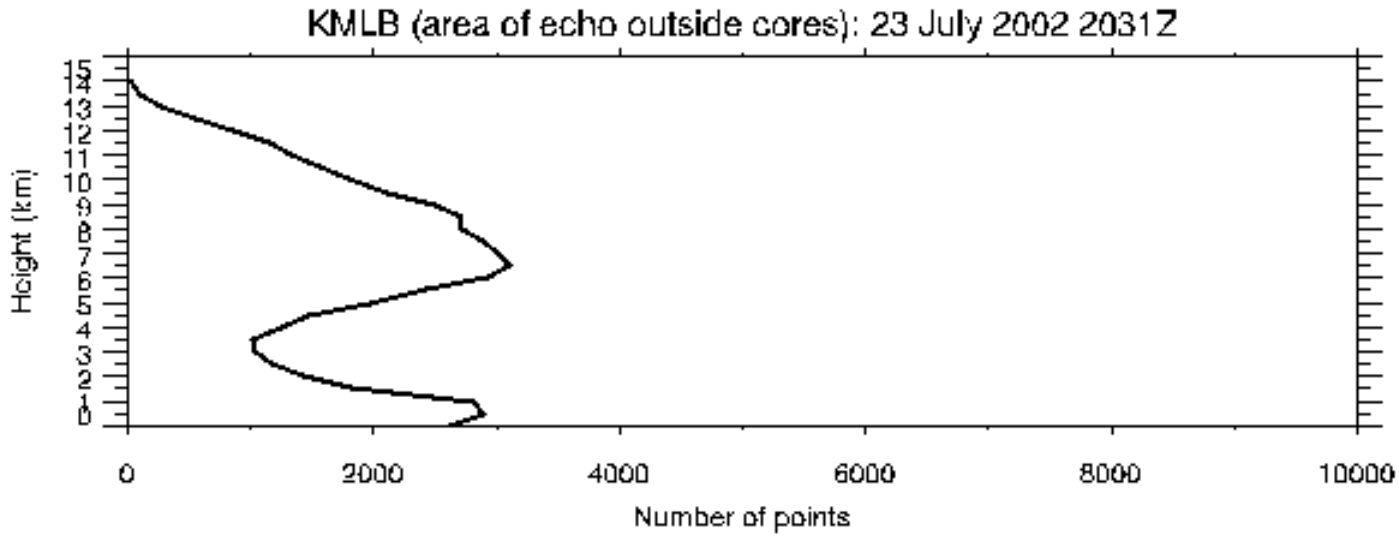
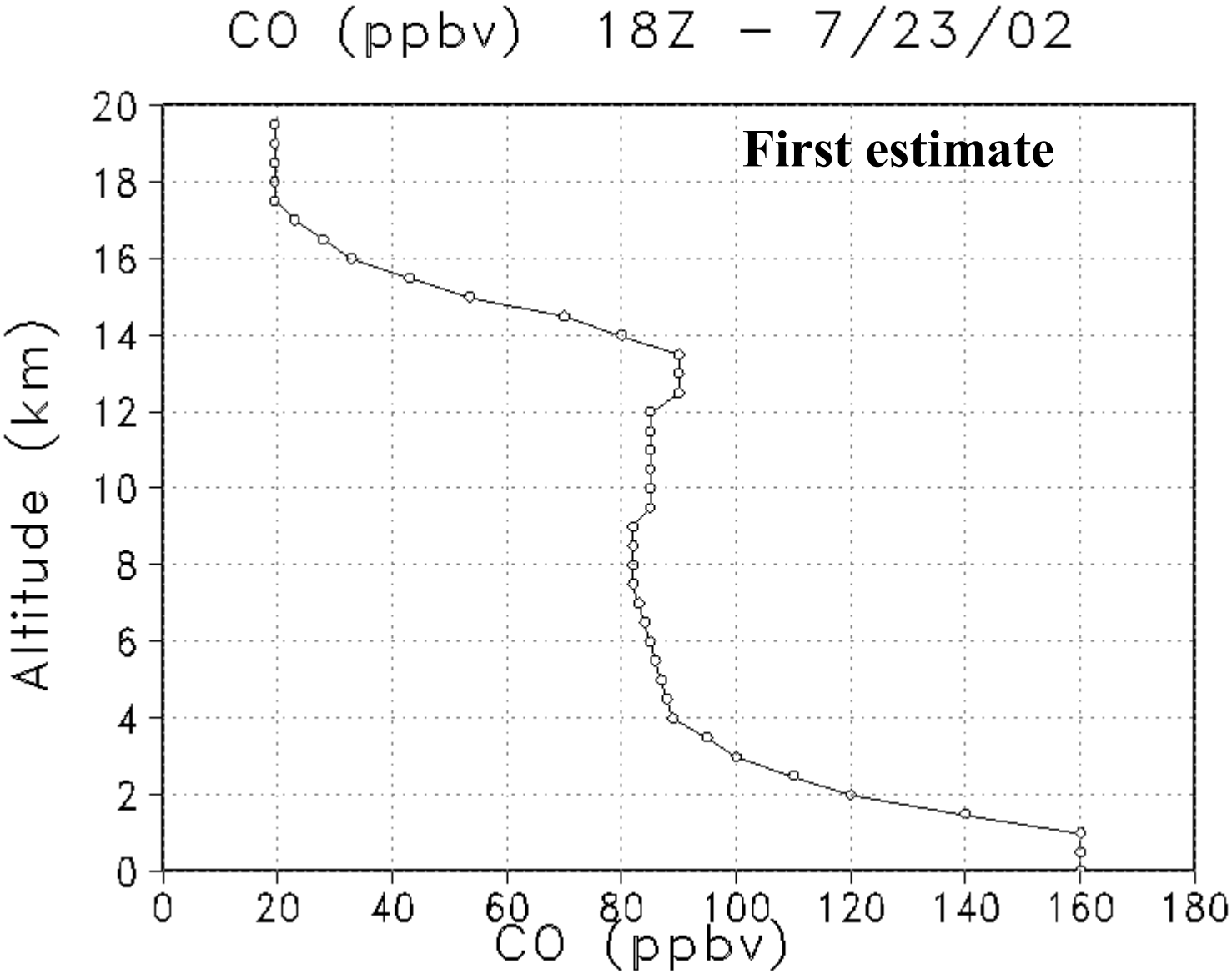
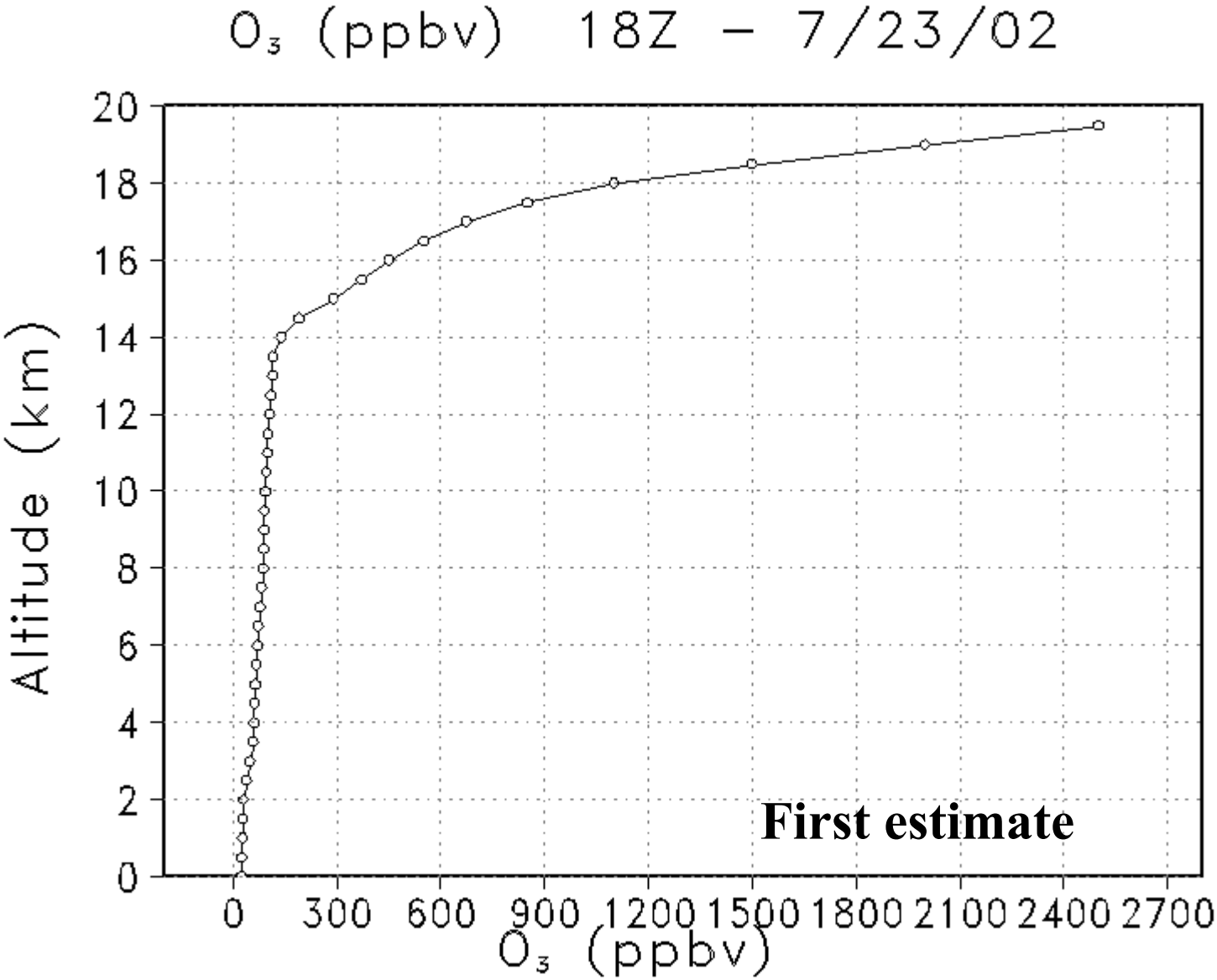
26.7N
26.6N
26.5N
26.4N
26.3N
81.3W
80.8W
80.3W
50
45
40
35
30
25
20
15
10
5
0

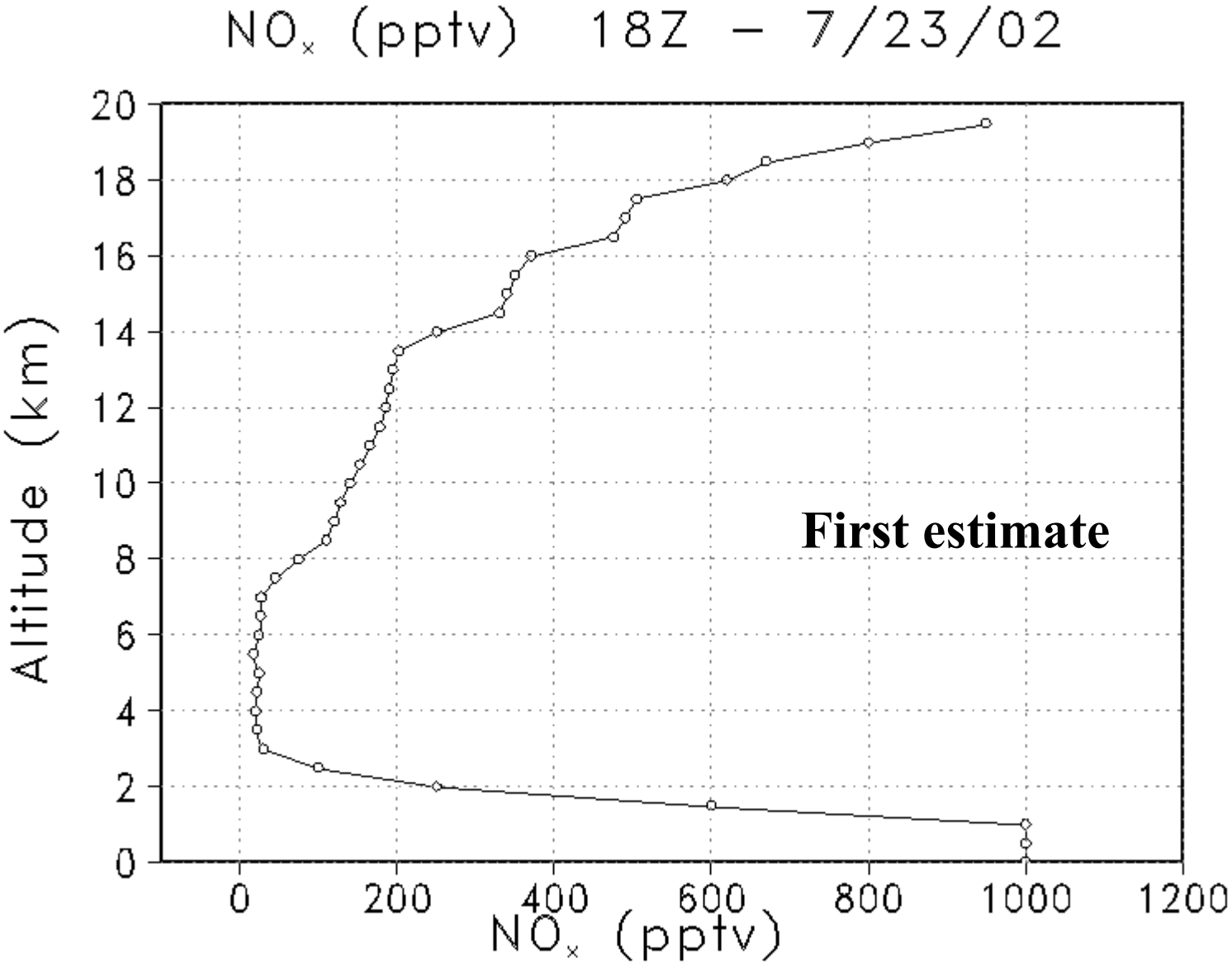

KMLB NEXRAD CAPPI at 2 km: 23 July 2002 2031Z
28
27
-82
-81
-80
60
55
50
45
40
35
30
25
20
15
10
5
0
(dBZ)
Contours: dBZ CAPPI at 9 km (every 10 dBZ starting at 0)
Image: dBZ CAPPI at 2 km

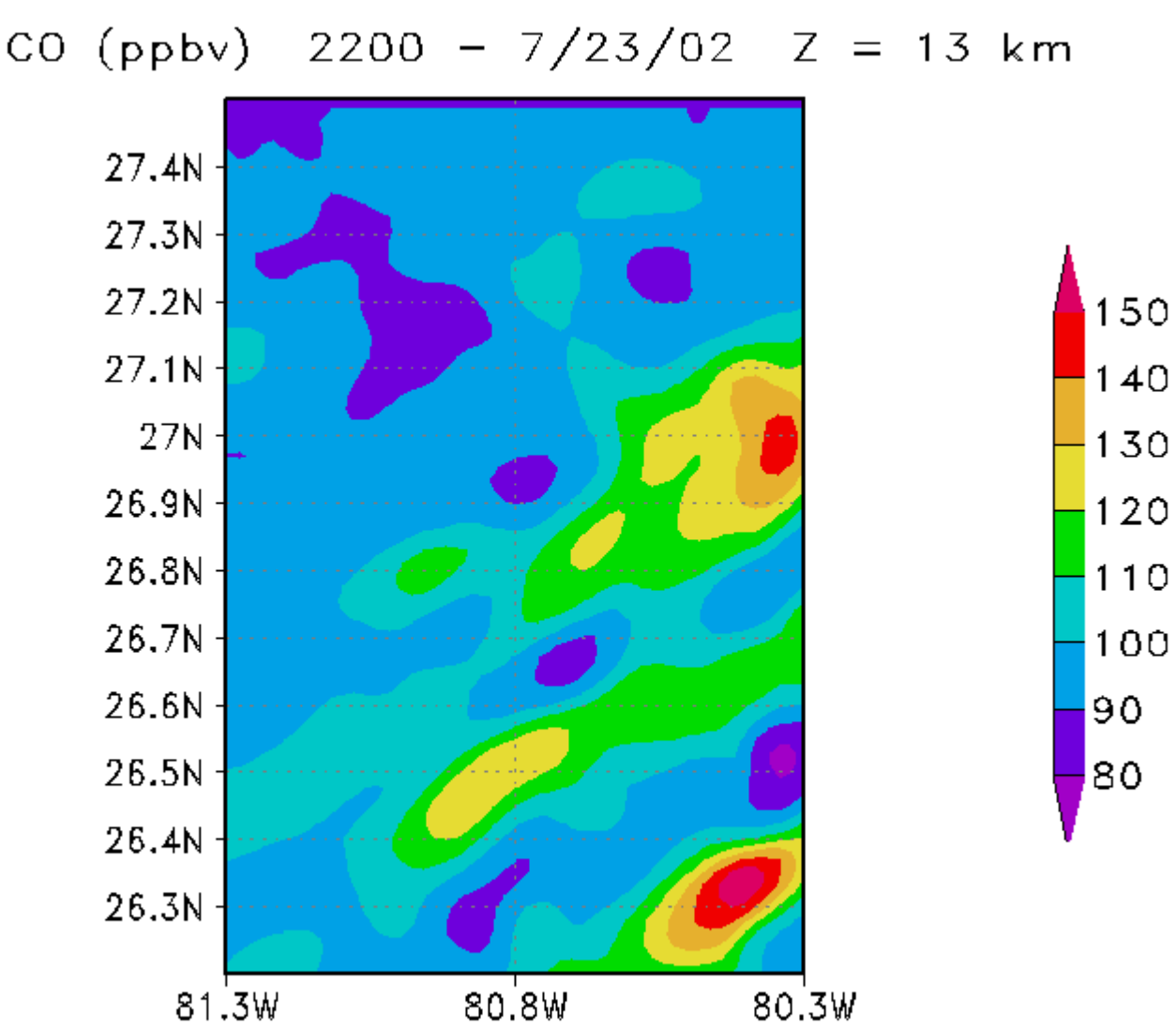

KMLB (red:max, black:mean outside cores): 23 July 2002 2031Z
Height (km)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
-10
0
10
20
30
40
50
60
dBZ

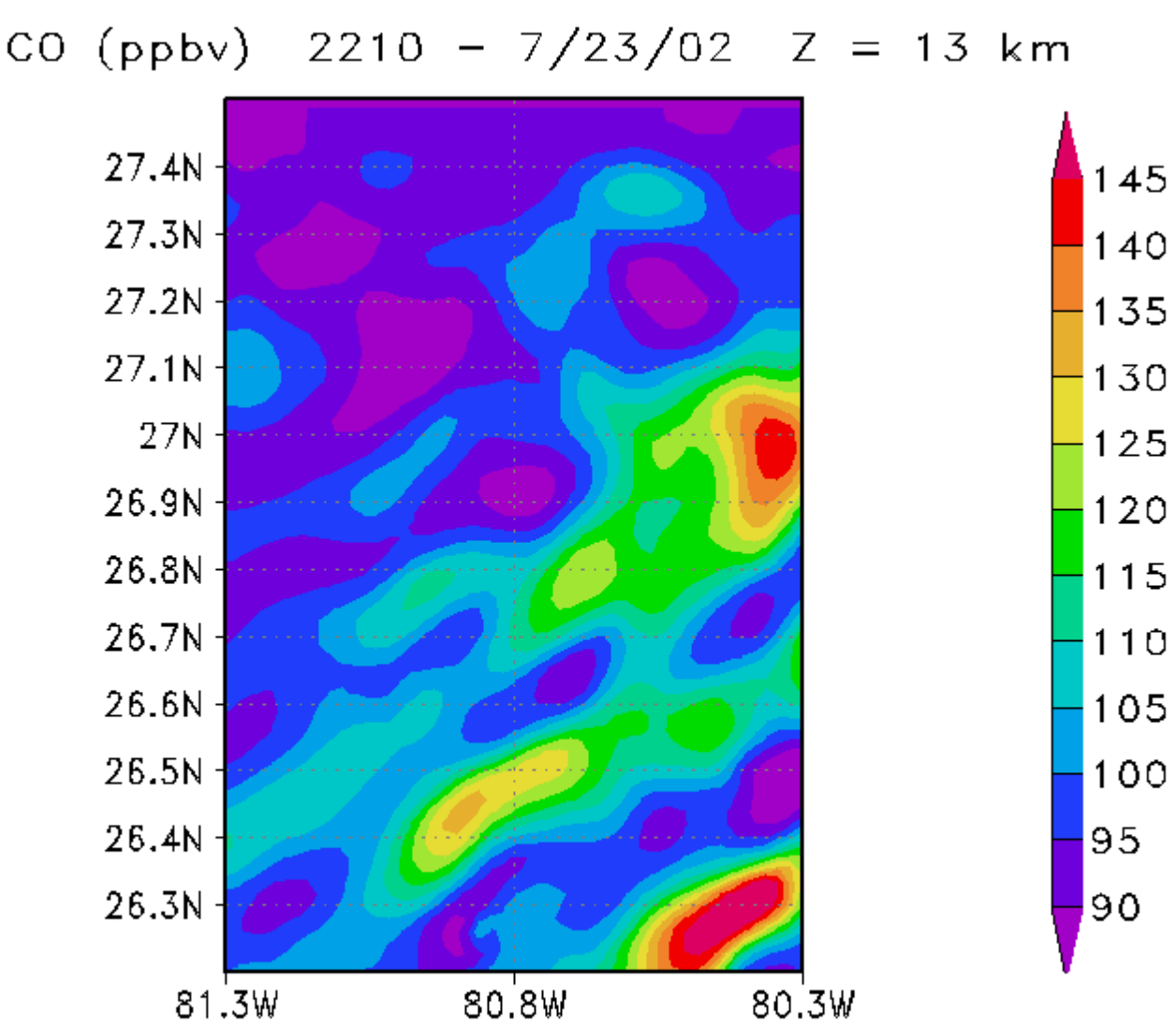

KMLB (area of echo outside cores): 23 July 2002 2031Z
Height (km)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
0
2000
4000
6000
8000
10000
Number of points


CO (ppbv) 18Z – 7/23/02
First estimate
Altitude (km)
0
2
4
6
8
10
12
14
16
18
20
0
20
40
60
80
100
120
140
160
180
CO (ppbv)


O₃ (ppbv) 18Z – 7/23/02
Altitude (km)
0
2
4
6
8
10
12
14
16
18
20
0
300
600
900
1200
1500
1800
2100
2400
2700
O₃ (ppbv)
First estimate


NOx (pptv) 18Z – 7/23/02
Altitude (km)
0
2
4
6
8
10
12
14
16
18
20
0
200
400
600
800
1000
1200
NOx (pptv)
First estimate


CO (ppbv) 2200 - 7/23/02 Z = 13 km
27.4N
27.3N
27.2N
27.1N
27N
26.9N
26.8N
26.7N
26.6N
26.5N
26.4N
26.3N
81.3W
80.8W
80.3W
150
140
130
120
110
100
90
80


CO (ppbv) 2210 - 7/23/02 Z = 13 km
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27.1N
27N
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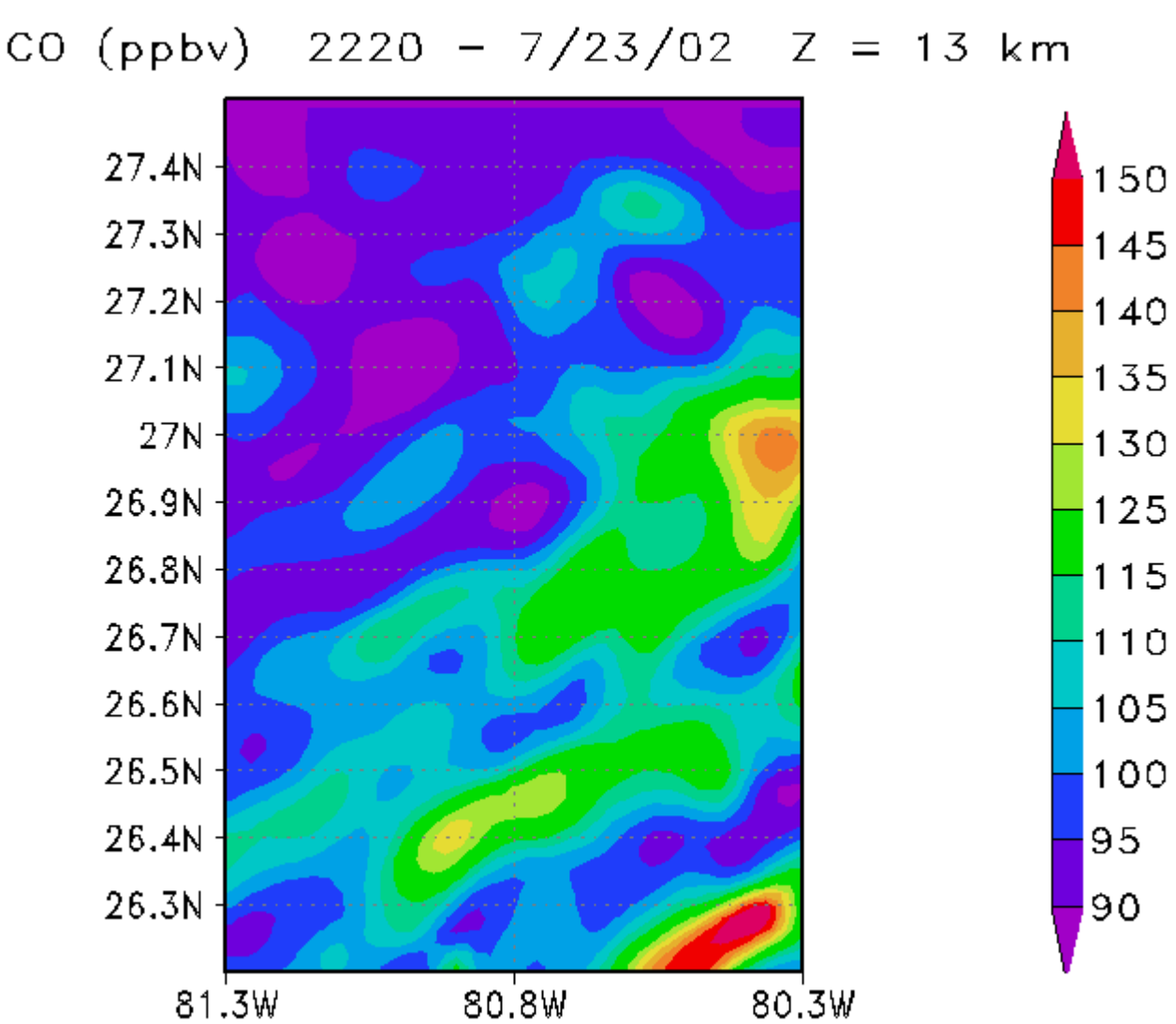
26.8N
26.7N
26.6N
26.5N
26.4N
26.3N
81.3W
80.8W
80.3W
145
140
135
130
125
120
115
110
105
100
95
90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26.6N
26.5N
26.4N
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80.8W
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150
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130
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100
95
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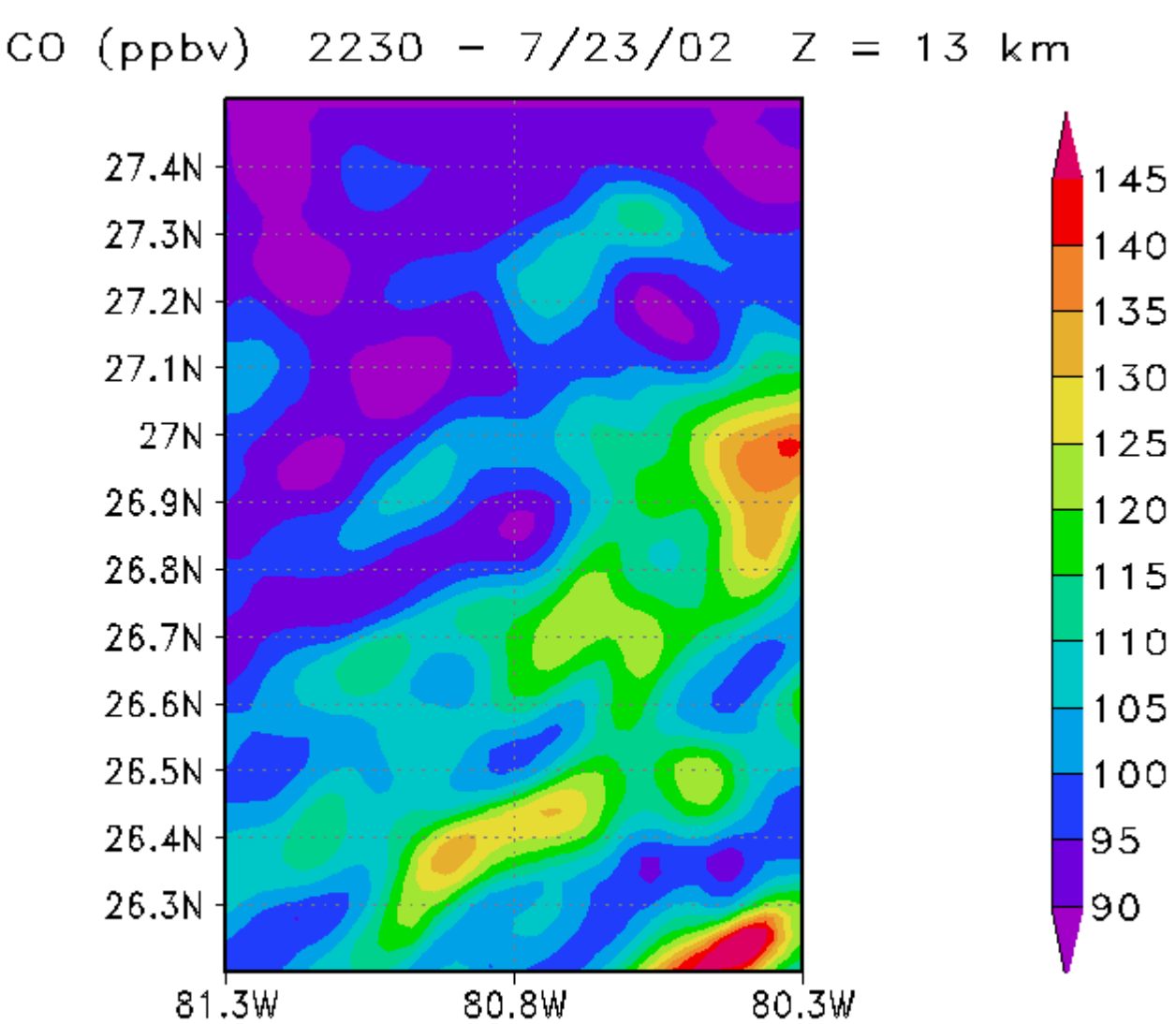
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26.4N
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80.3W
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135
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95
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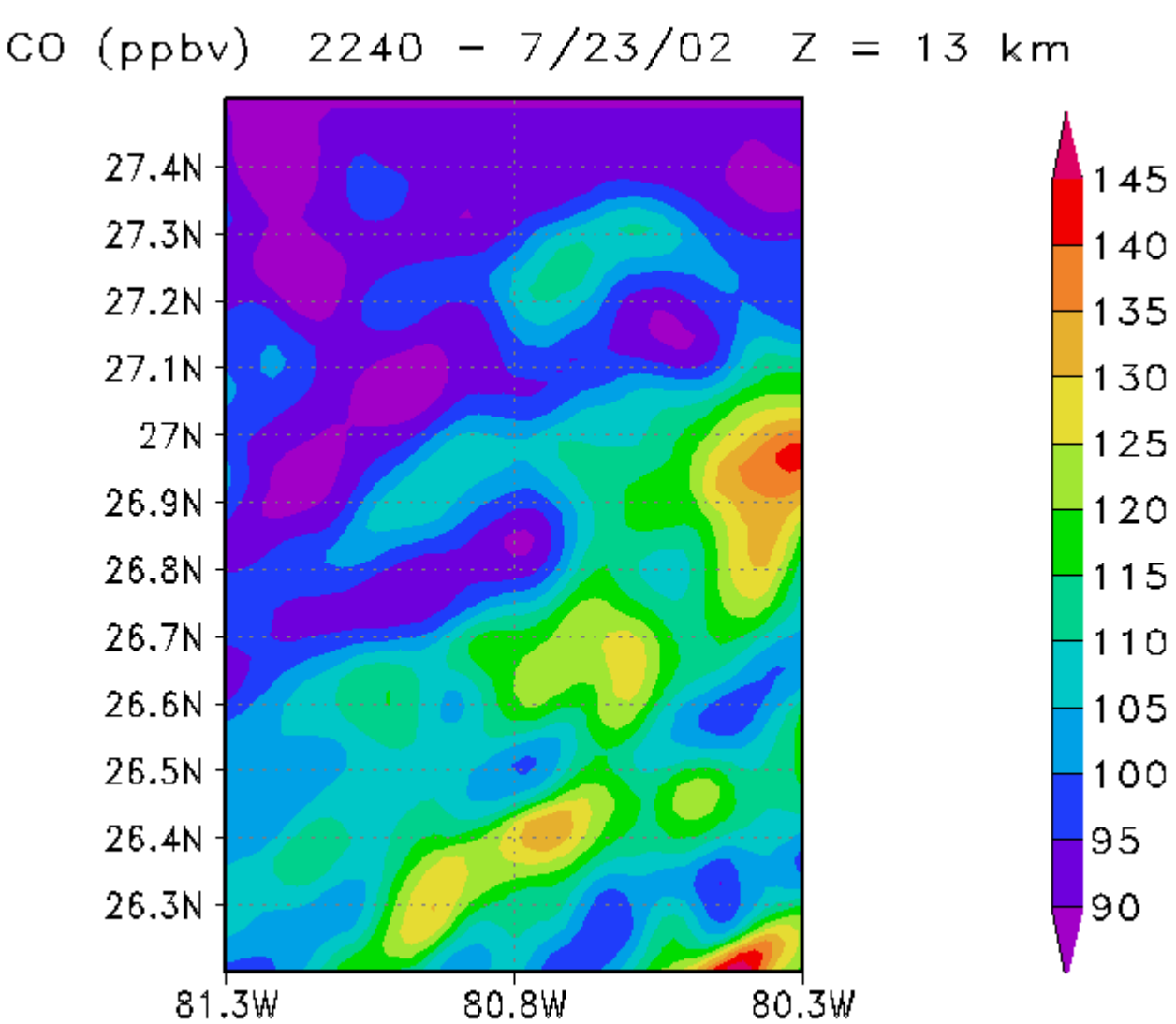
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26.6N
26.5N
26.4N
26.3N
81.3W
80.8W
80.3W
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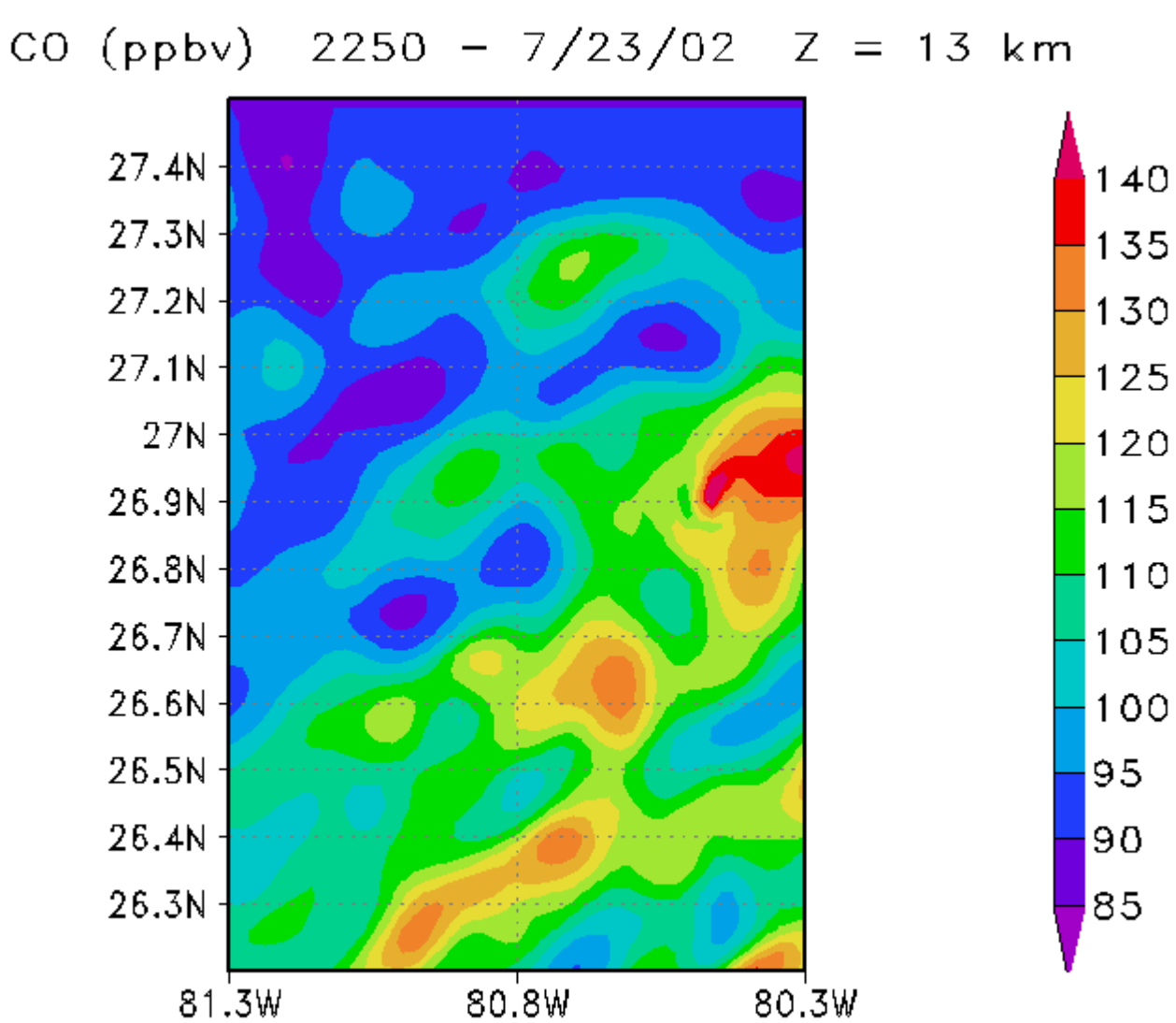
140
135
130
125
120
115
110
105
100
95
90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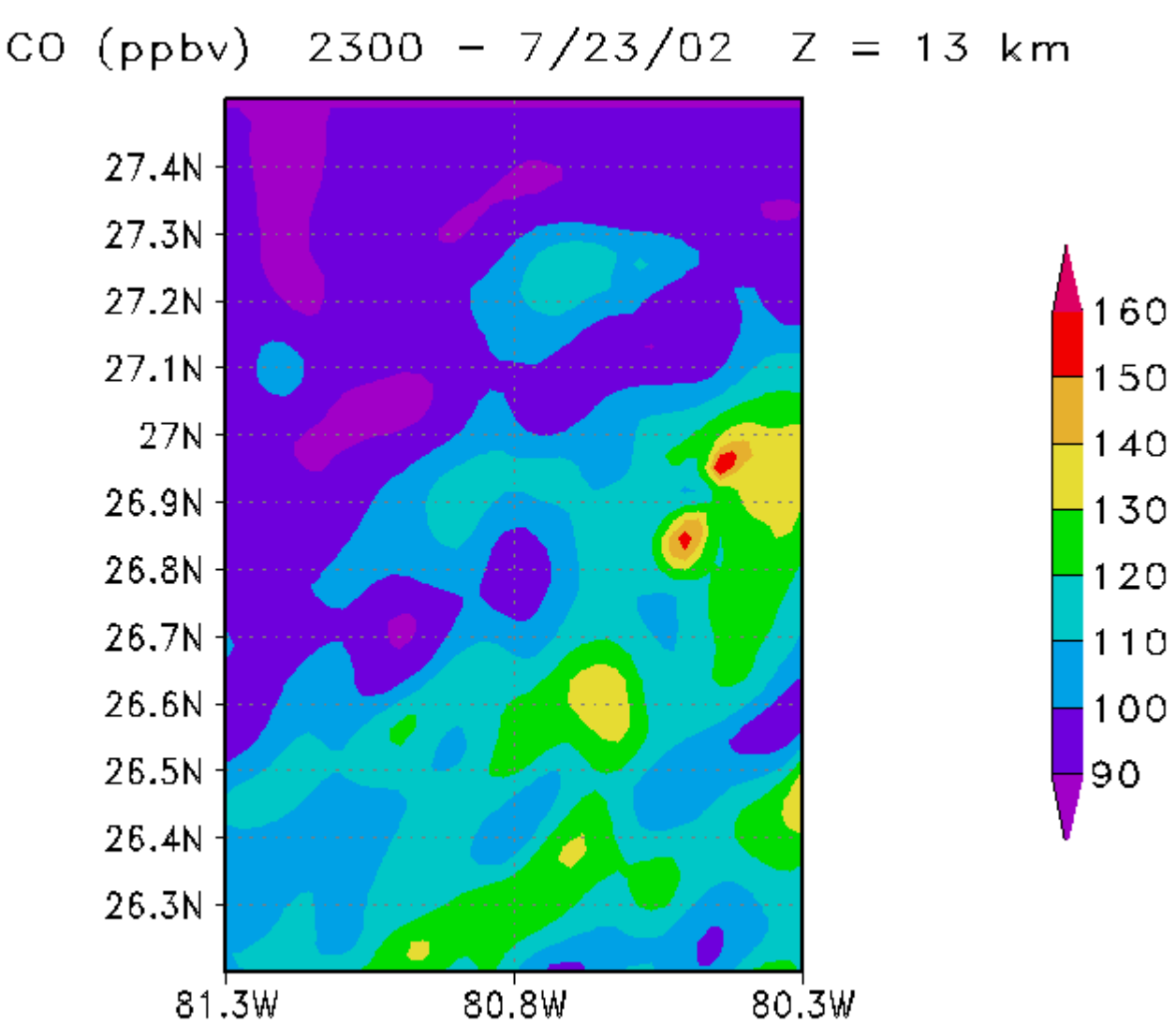
27.2N
27.1N
27N
26.9N
26.8N
26.7N
26.6N
26.5N
26.4N
26.3N
81.3W
80.8W
80.3W
140
135
130
125
120
115
110
105
100
95
90
85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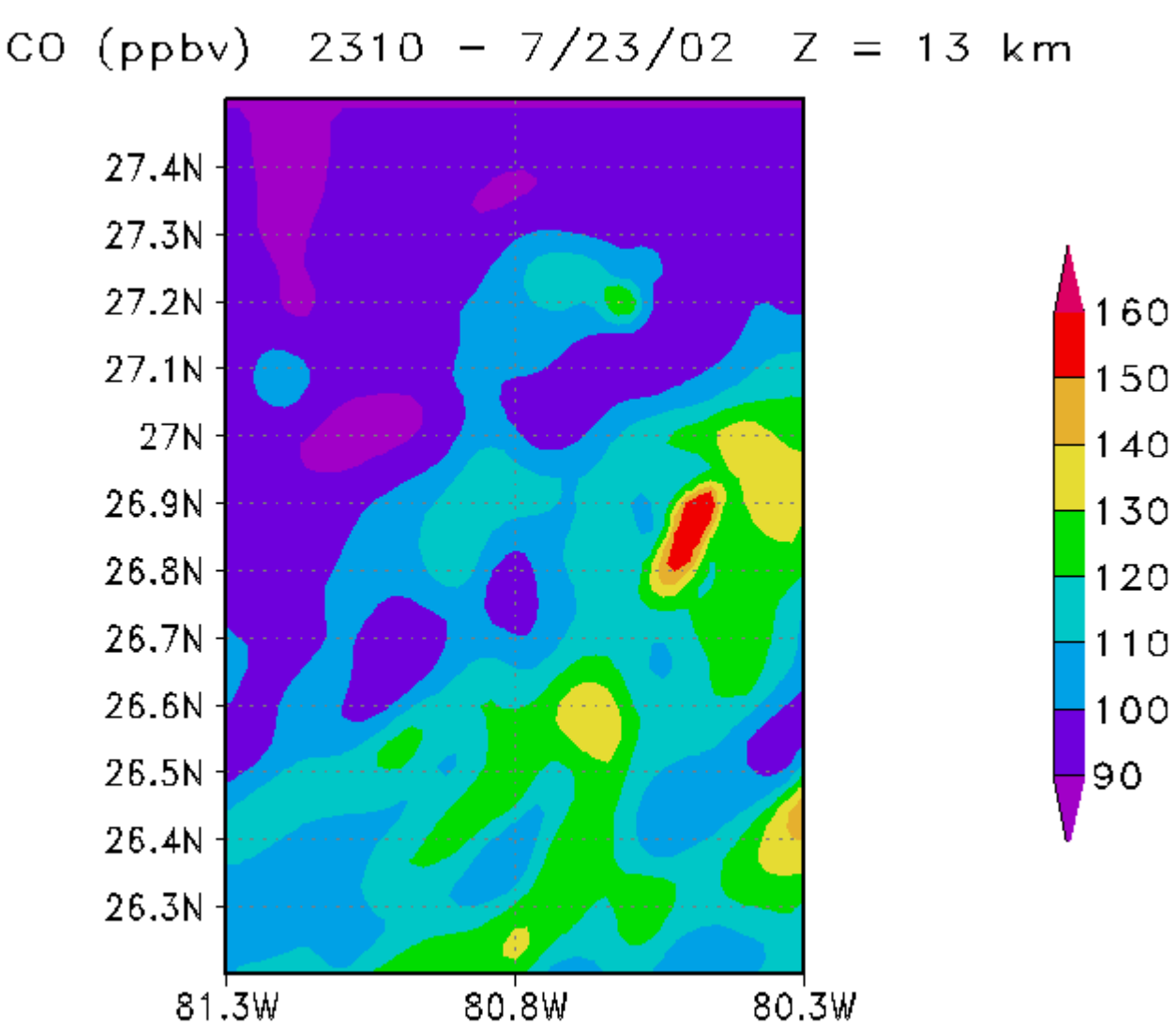
27.3N
27.2N
27.1N
27N
26.9N
26.8N
26.7N
26.6N
26.5N
26.4N
26.3N
81.3W
80.8W
80.3W
160
150
140
130
120
110
100
90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27.3N
27.2N
27.1N
27N
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26.6N
26.5N
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26.3N
81.3W
80.8W
80.3W
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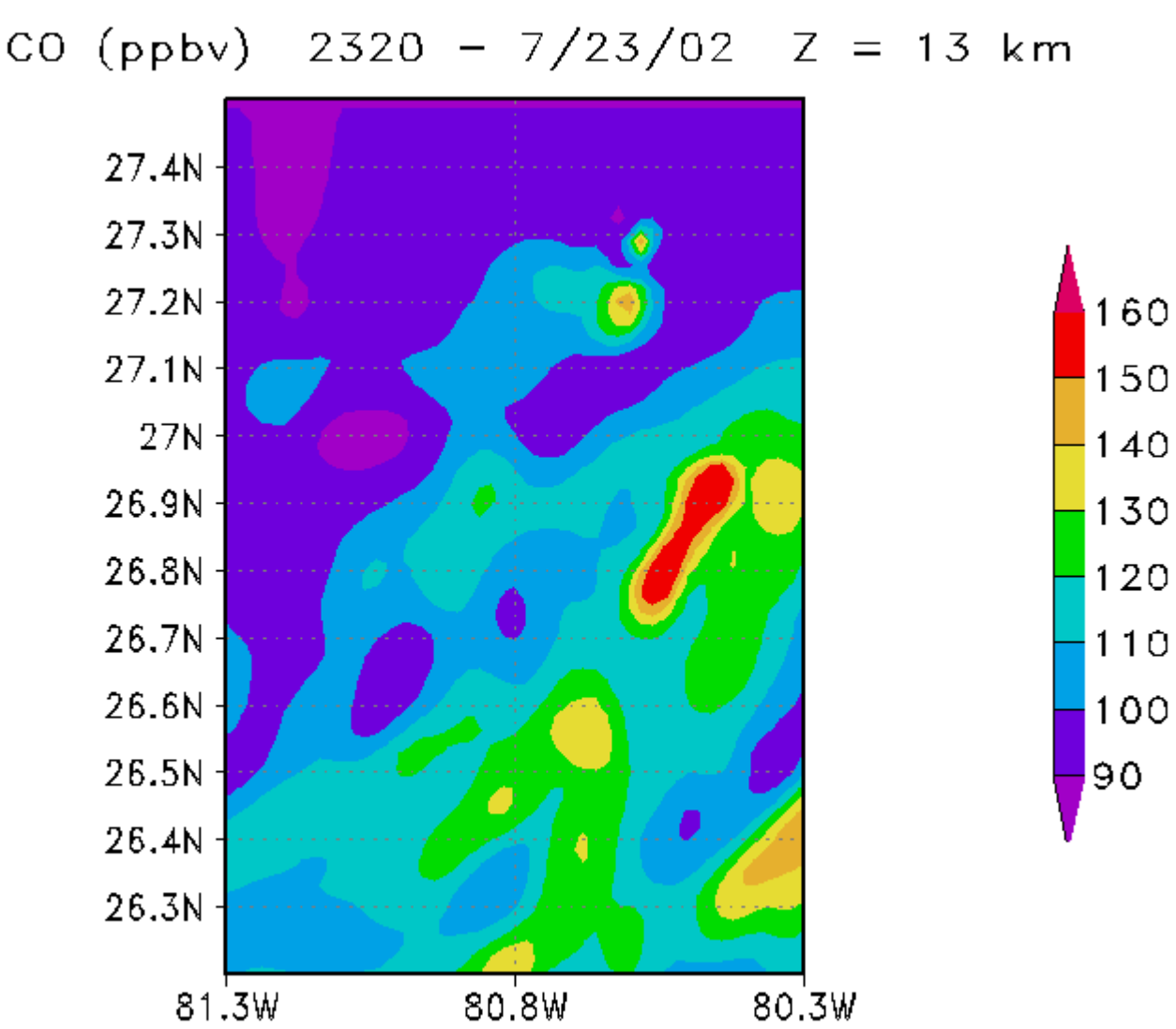
150
140
130
120
110
100
90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27.3N
27.2N
27.1N
27N
26.9N
26.8N
26.7N
26.6N
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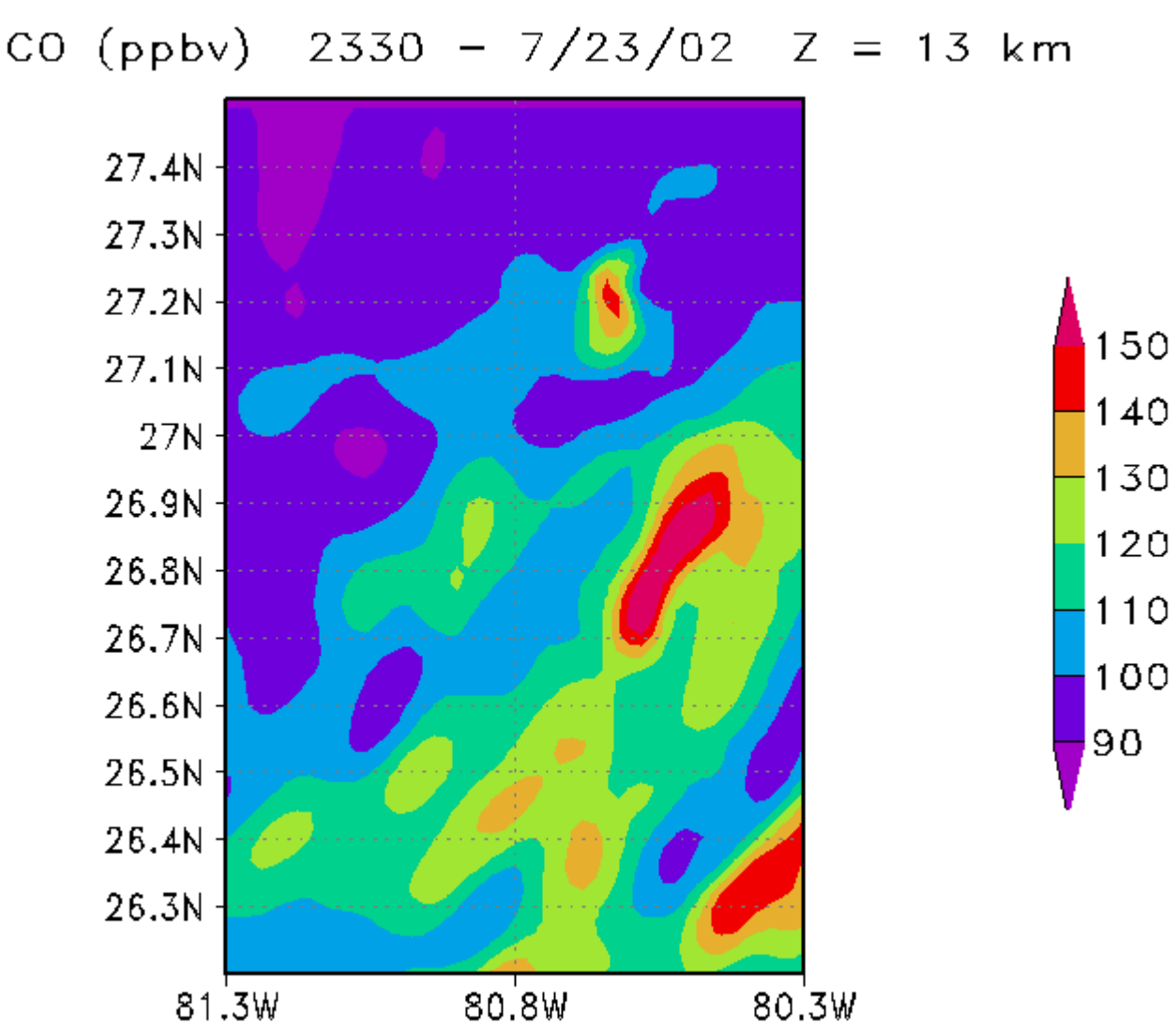
80.3W
160
150
140
130
120
110
100
90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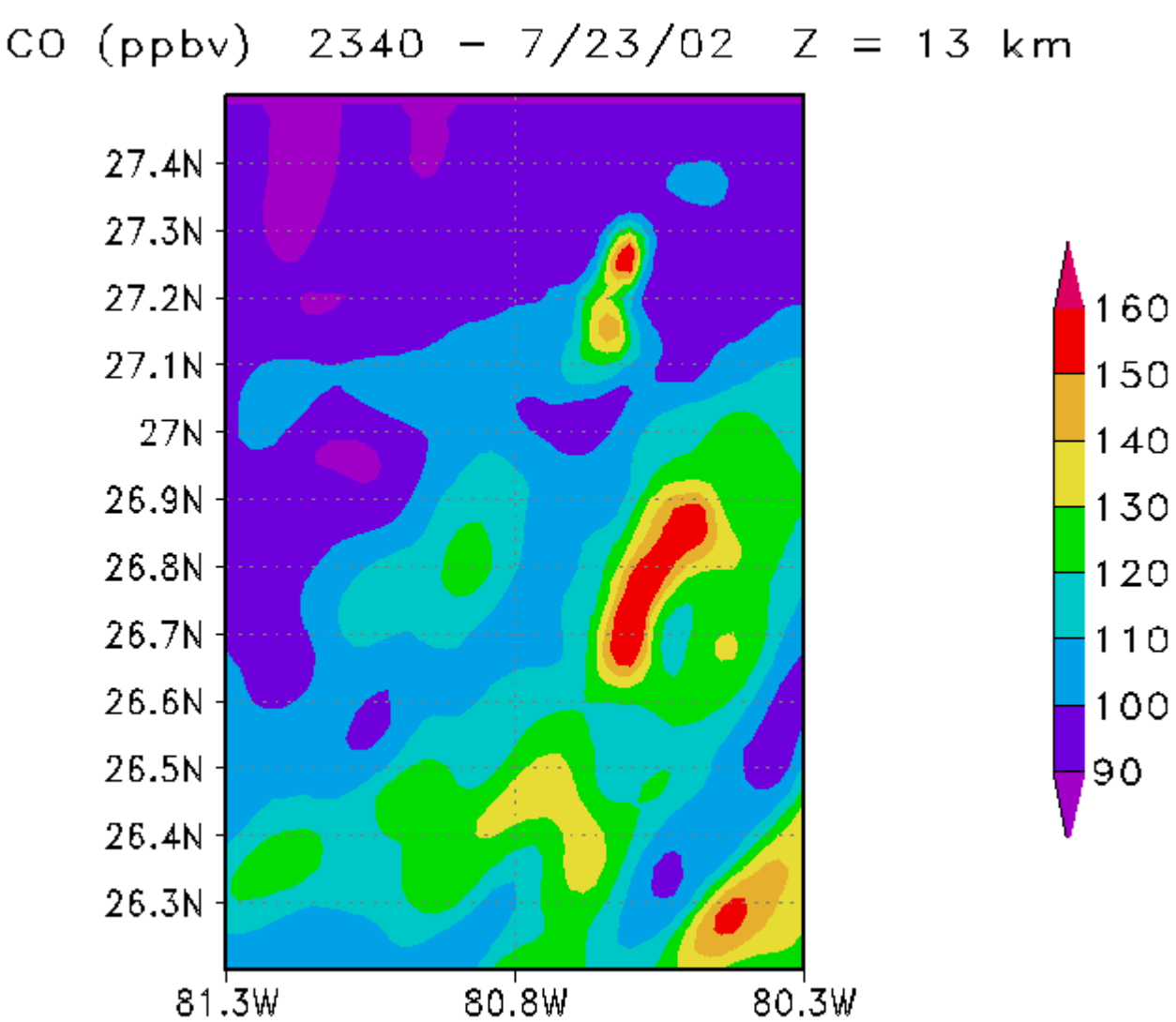
27.3N
27.2N
27.1N
27N
26.9N
26.8N
26.7N
26.6N
26.5N
26.4N
26.3N
81.3W
80.8W
80.3W
150
140
130
120
110
100
90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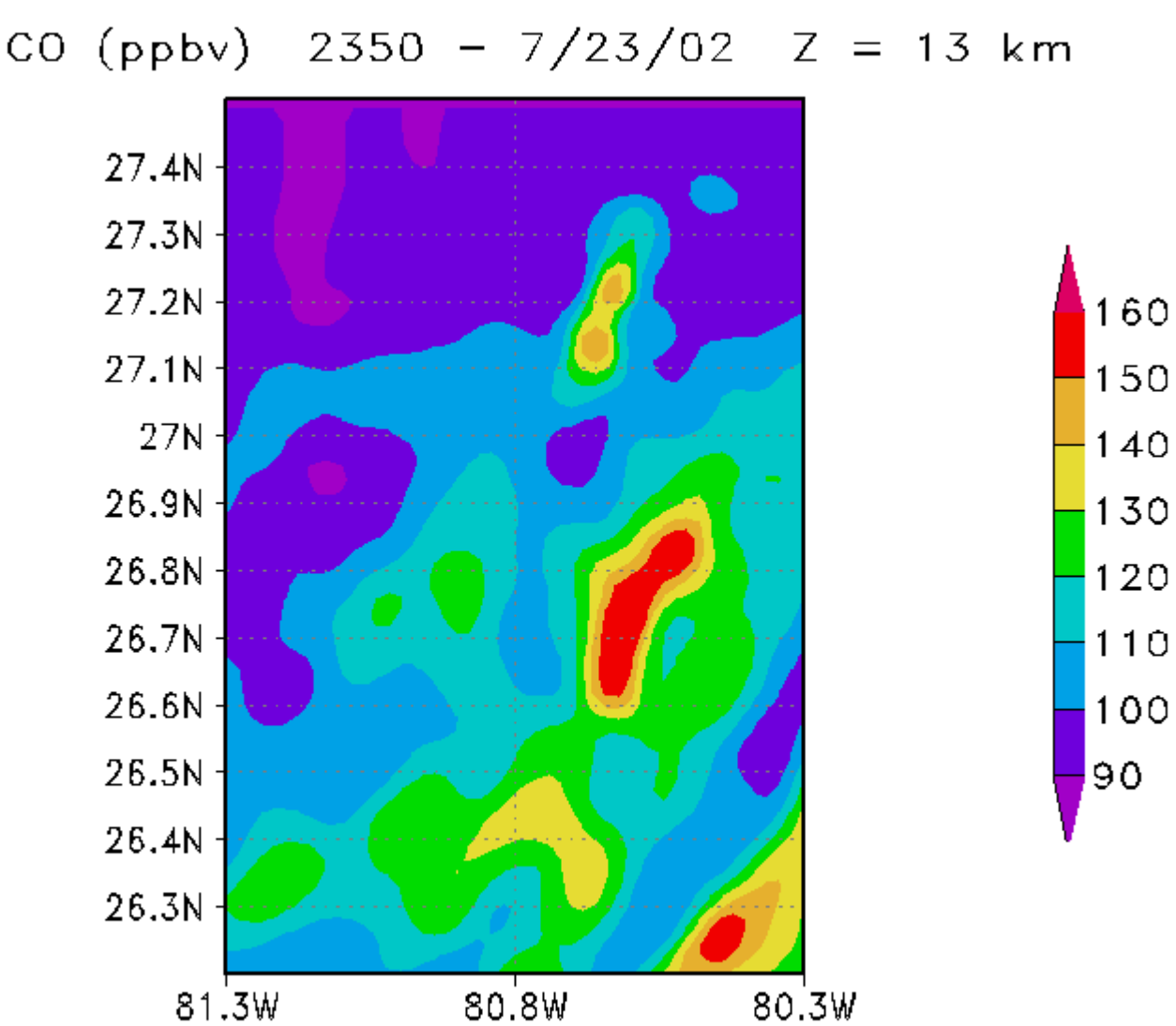
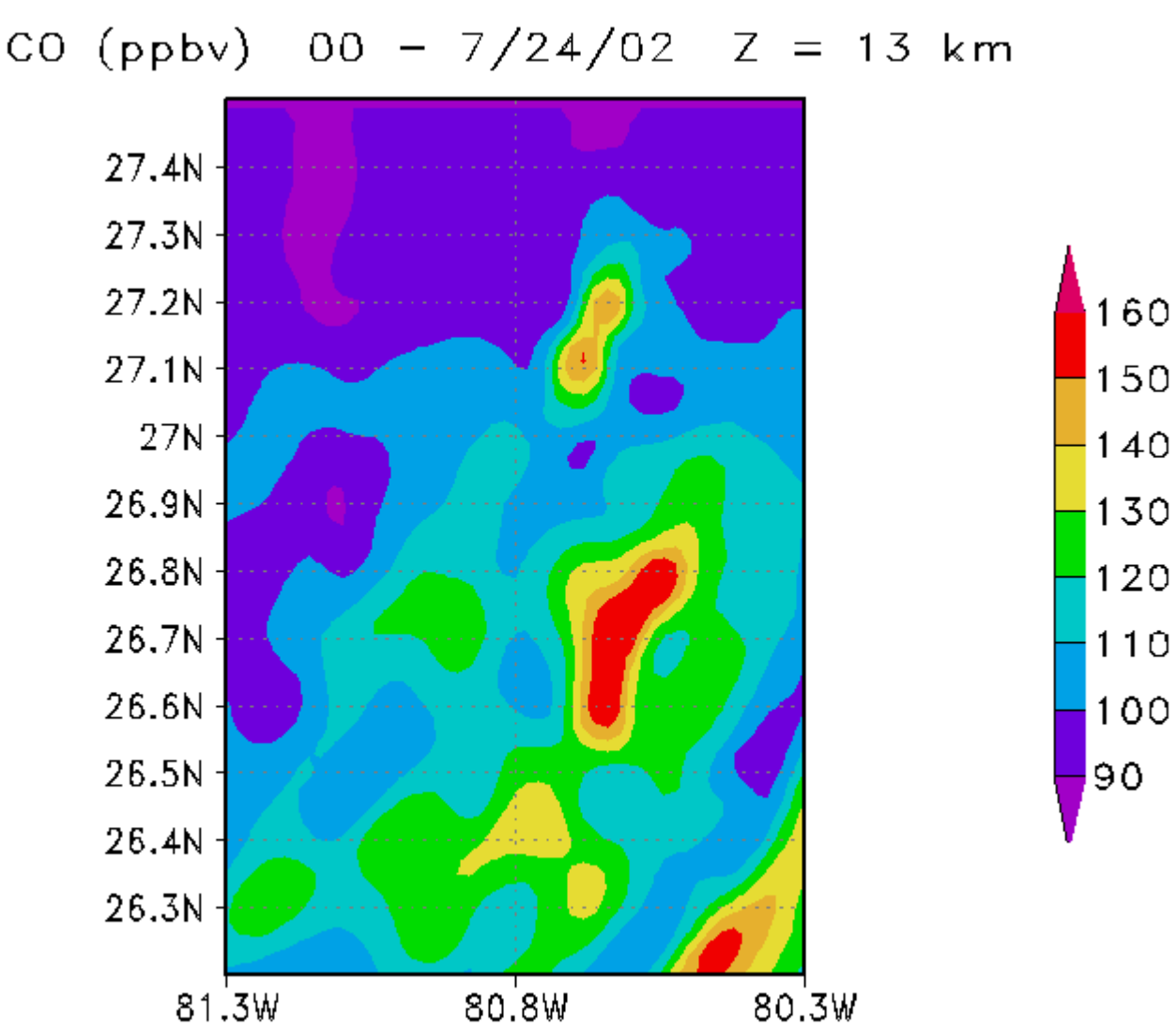
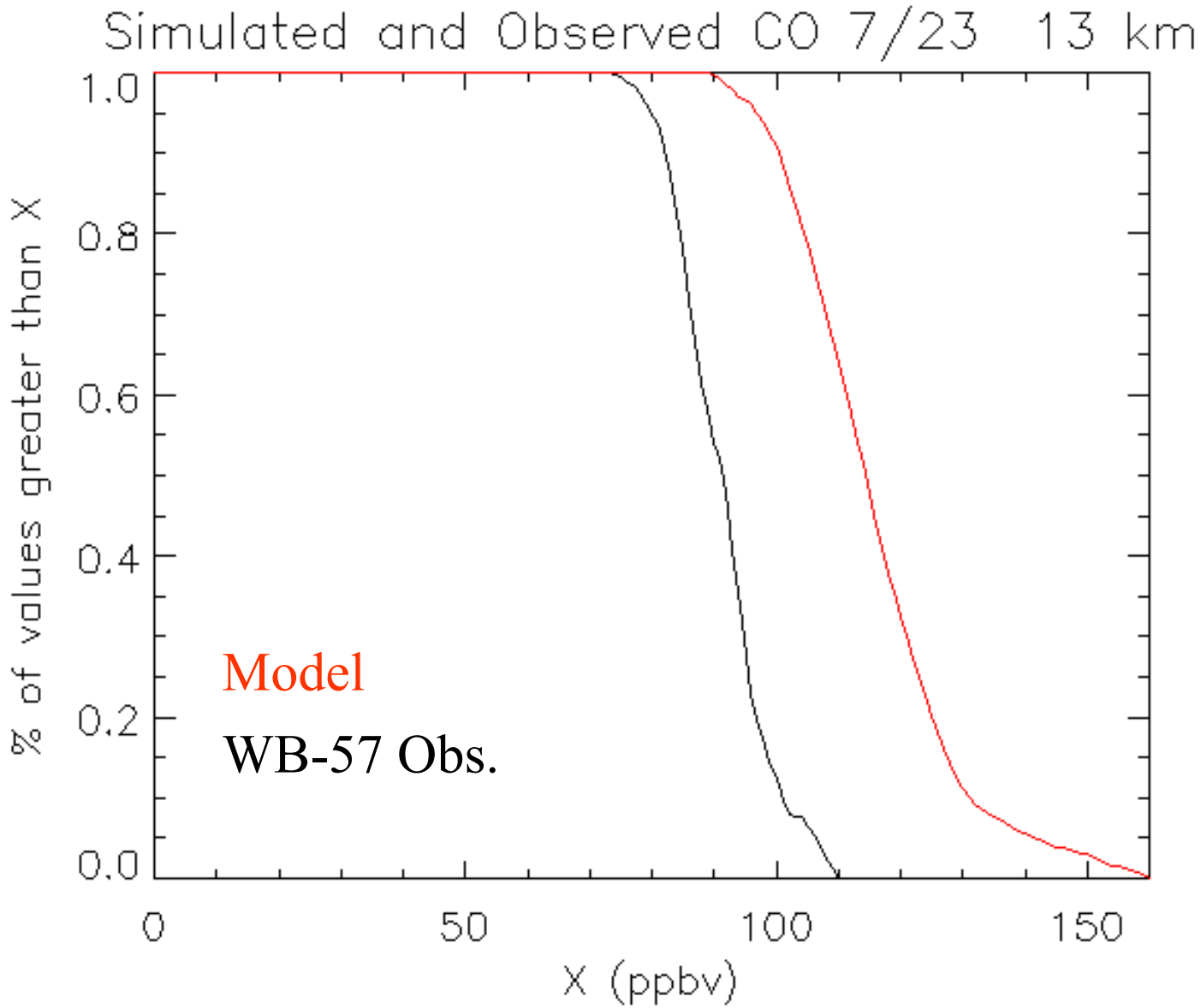
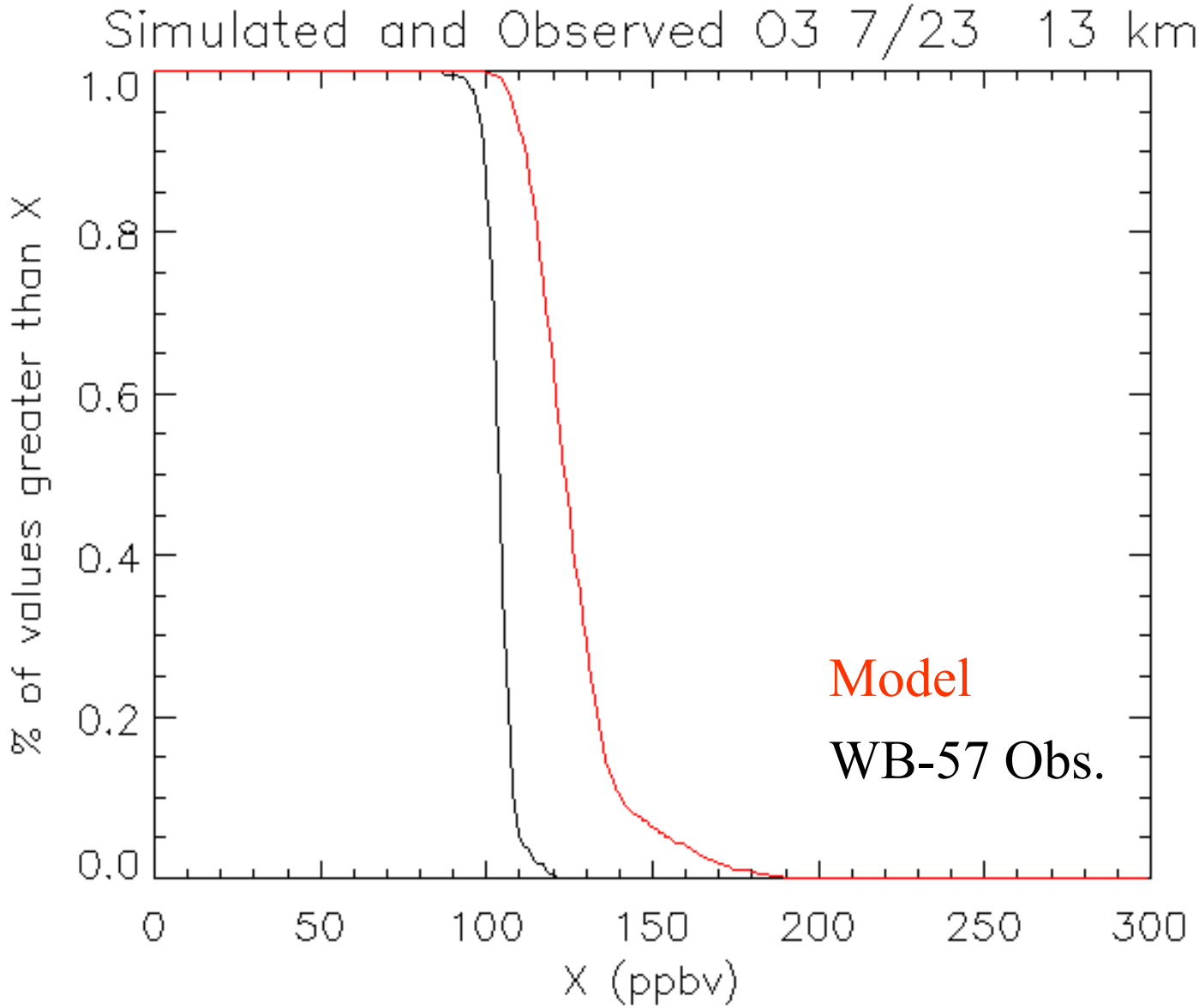
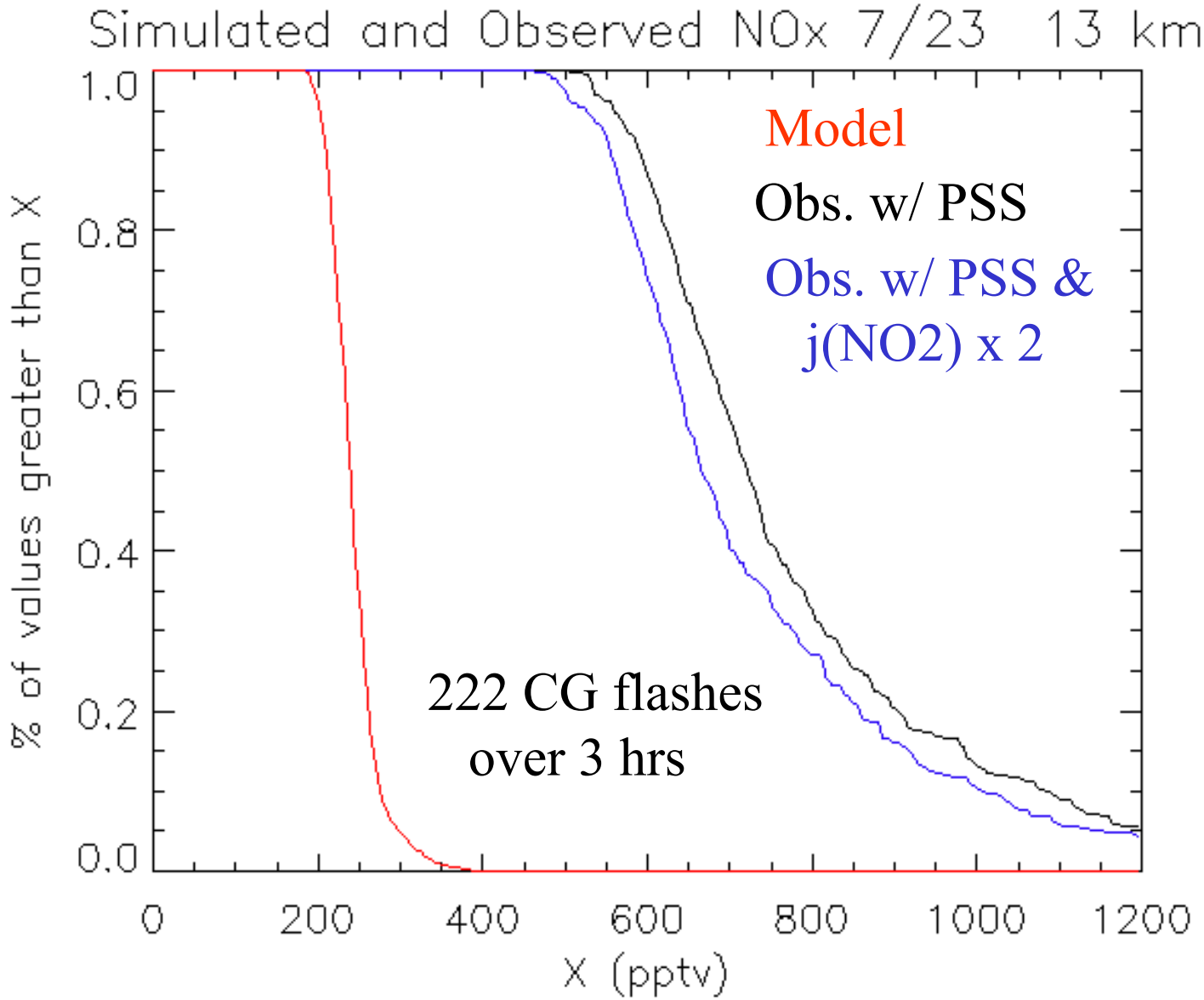
27.2N
27.1N
27N
26.9N
26.8N
26.7N
26.6N
26.5N
26.4N
26.3N
81.3W
80.8W
80.3W
160
150
140
130
120
110
100
90

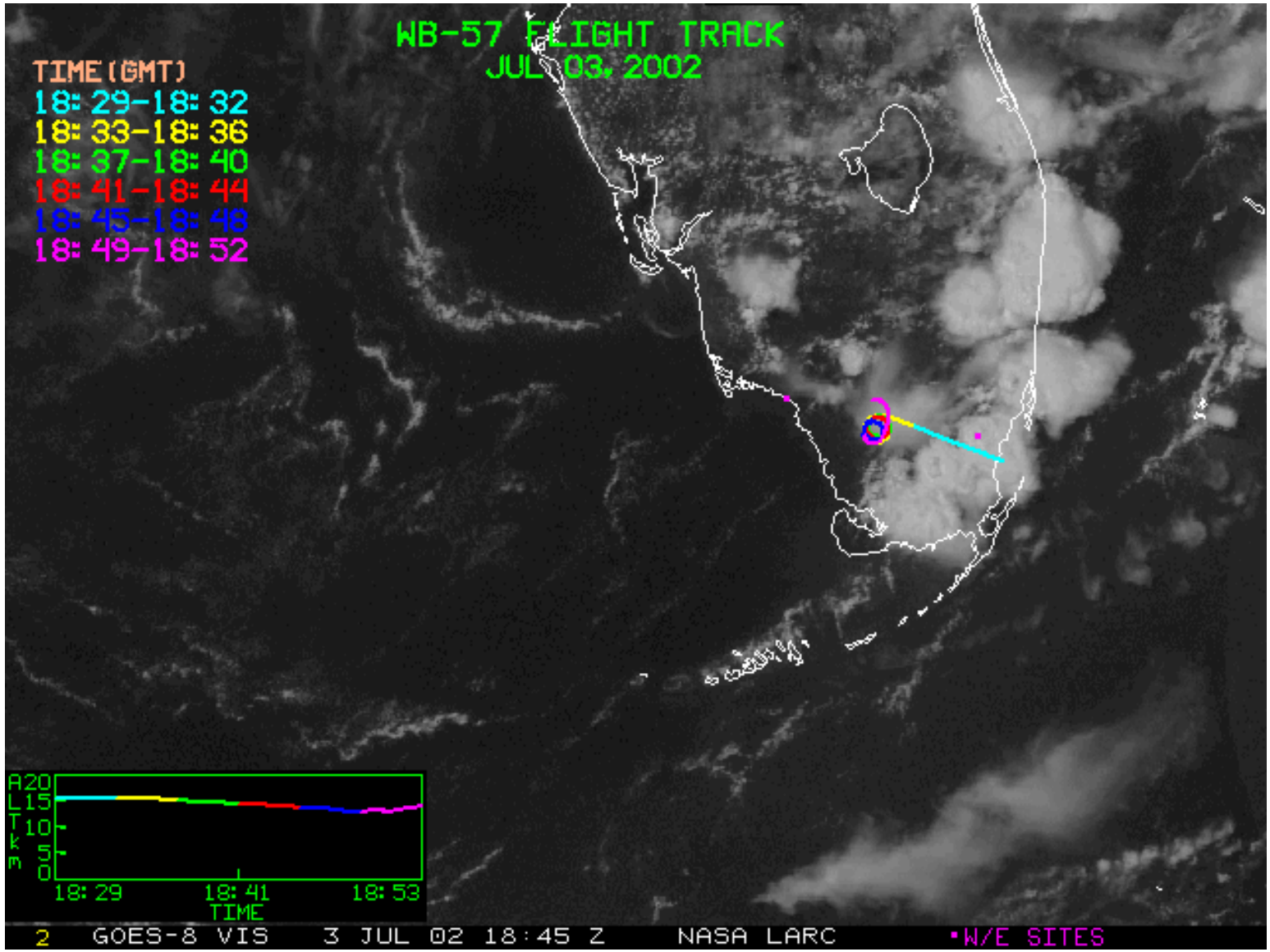

CO (ppbv) 2350 - 7/23/02 Z = 13 km
27.4N
27.3N
27.2N
27.1N
27N
26.9N
26.8N
26.7N
26.6N
26.5N
26.4N
26.3N
81.3W
80.8W
80.3W
160
150
140
130
120
110
100
90

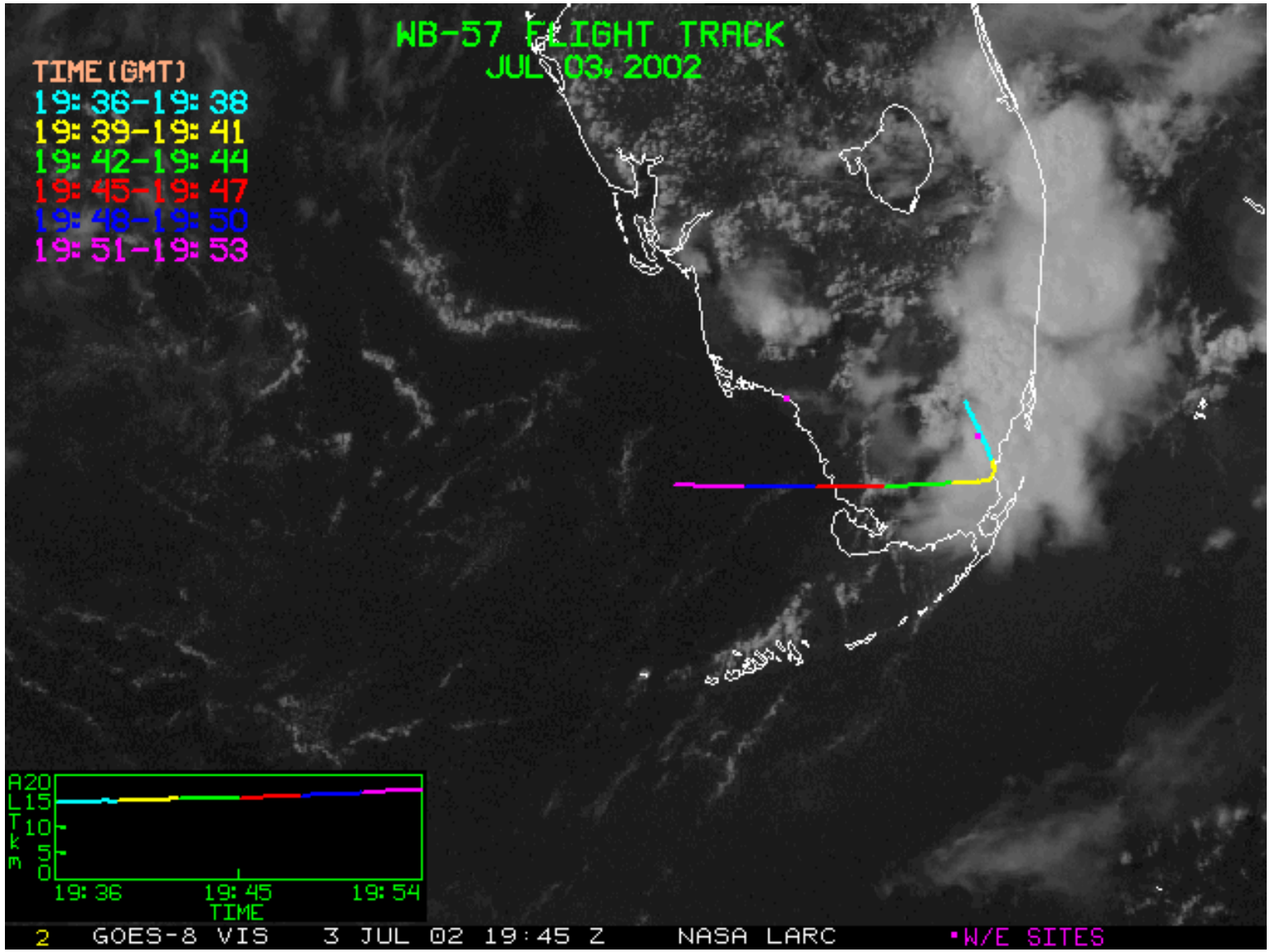

CO (ppbv) 00 - 7/24/02 Z = 13 km
27.4N
27.3N
27.2N
27.1N
27N
26.9N
26.8N
26.7N
26.6N
26.5N
26.4N
26.3N
81.3W
80.8W
80.3W
160
150
140
130
120
110
100
90

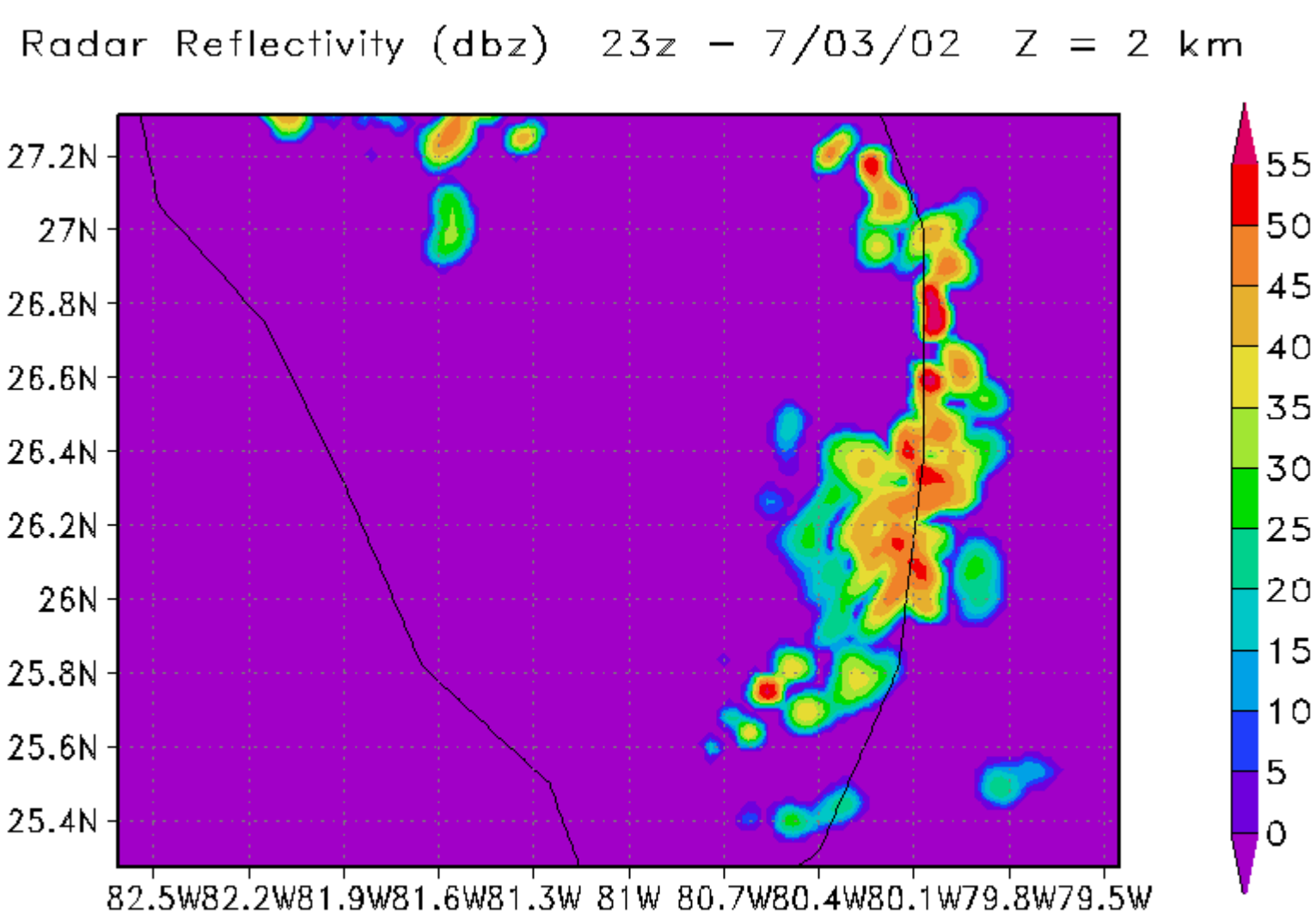

Simulated and Observed CO 7/23 13 km
% of values greater than X
1.0
0.8
0.6
0.4
0.2
0.0
0
50
100
150
X (ppbv)
Model
WB-57 Obs.

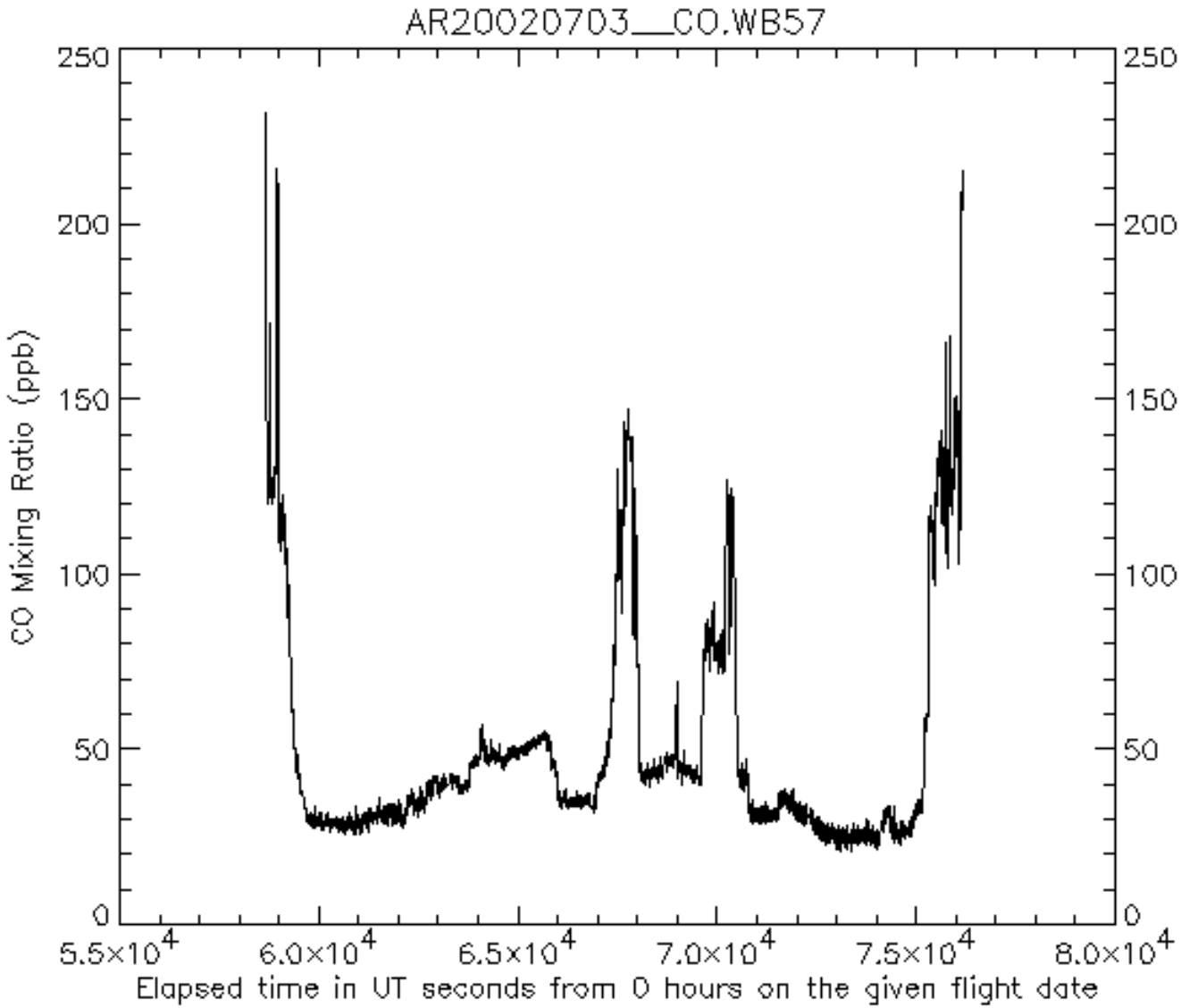

Simulated and Observed O3 7/23 13 km
% of values greater than X
1.0
0.8
0.6
0.4
0.2
0.0
0
50
100
150
200
250
300
X (ppbv)
Model
WB-57 Obs.

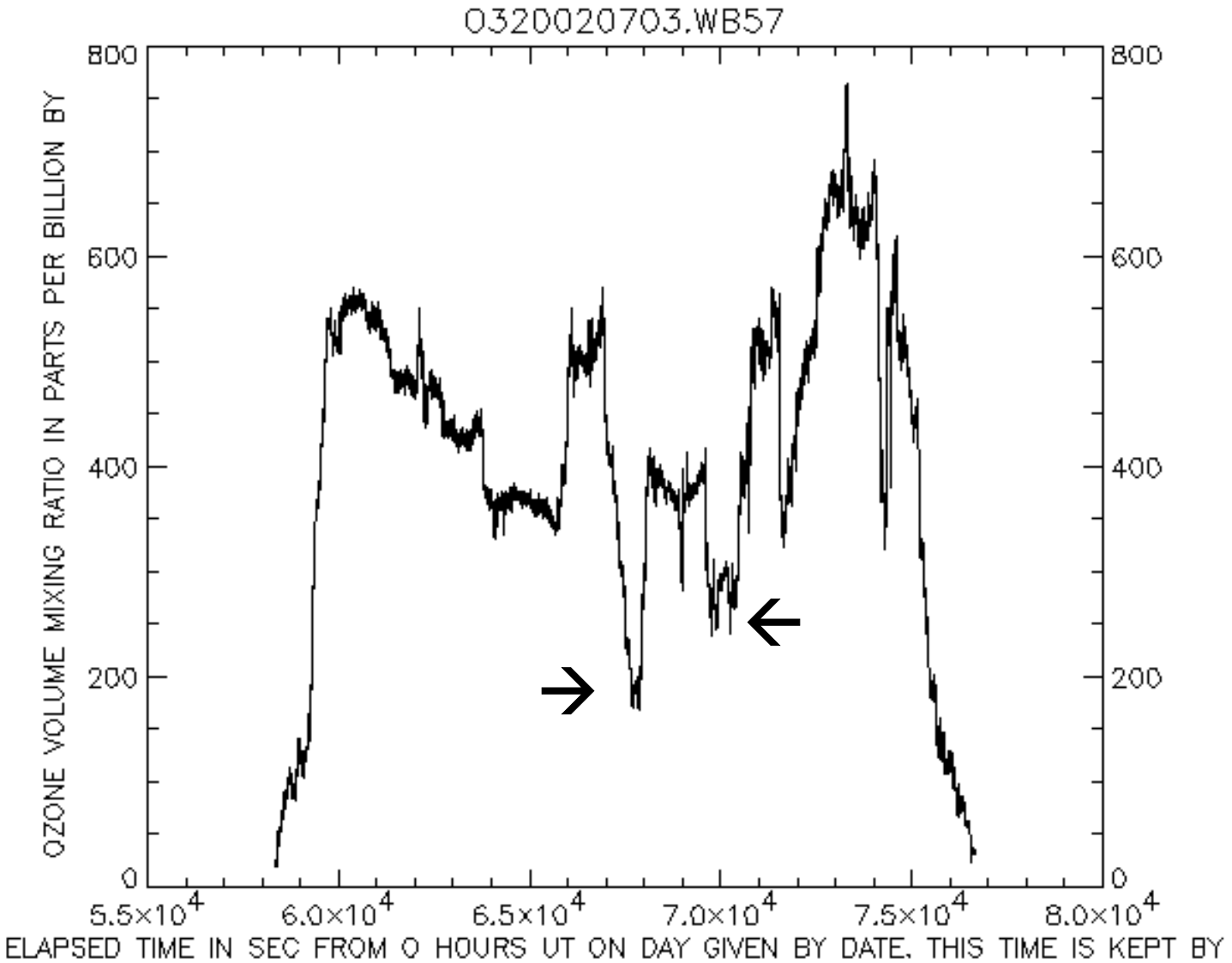

Simulated and Observed NOx 7/23 13 km
% of values greater than X
1.0
0.8
0.6
0.4
0.2
0.0
0
200
400
600
800
1000
1200
X (pptv)
Model
Obs. w/ PSS
Obs. w/ PSS &
j(NO2) x 2
222 CG flashes
over 3 hrs

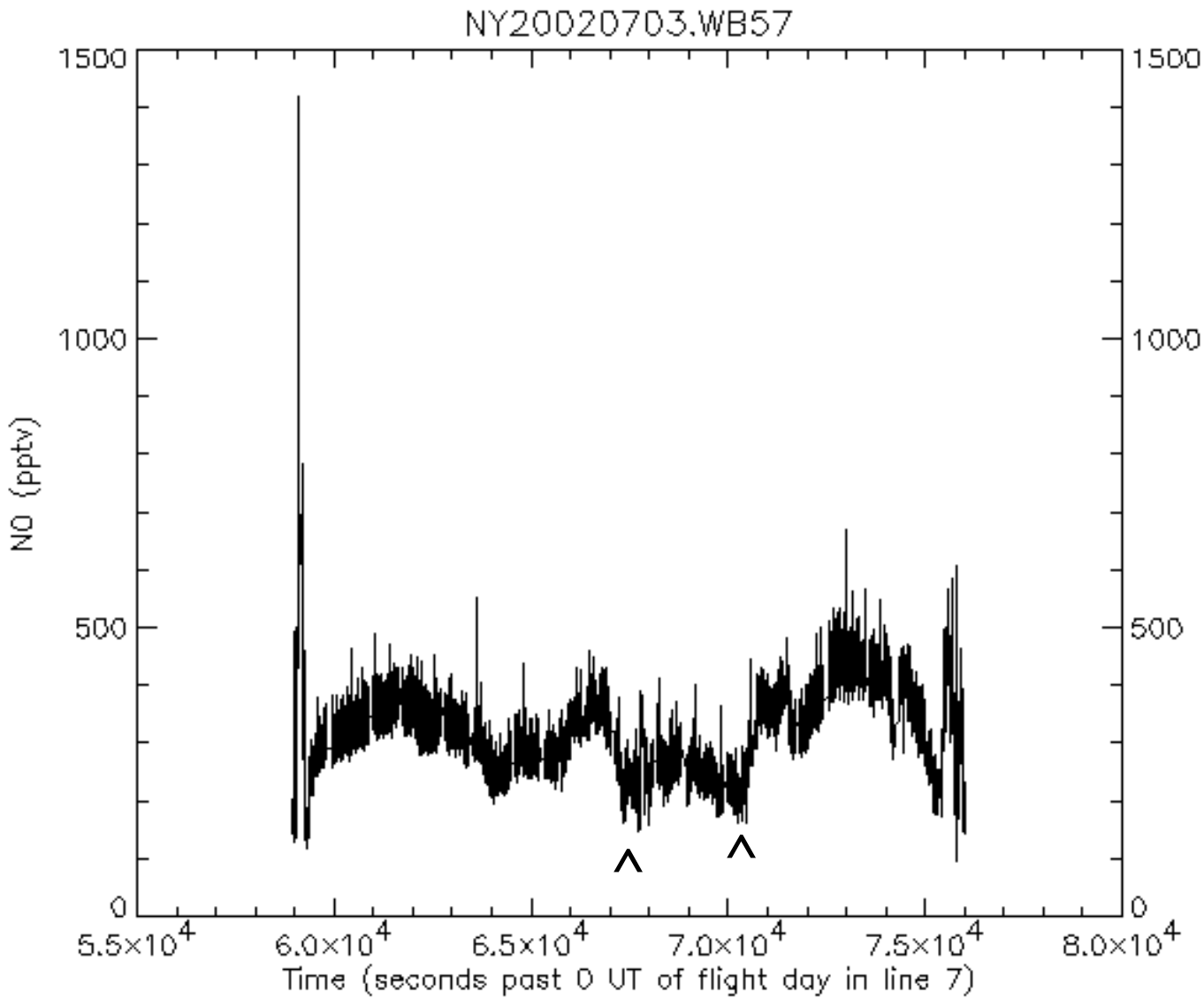

WB-57 FLIGHT TRACK
JUL 03, 2002
TIME(GMT)
18:29-18:32
18:33-18:36
18:37-18:40
18:41-18:44
18:45-18:48
18:49-18:52
ALT km
20
15
10
5
0
18:29
18:41
18:53
TIME
2 GOES-8 VIS 3 JUL 02 18:45 Z NASA LARC
W/E SITES


WB-57 FLIGHT TRACK
JUL 03, 2002
TIME(GMT)
19:36-19:38
19:39-19:41
19:42-19:44
19:45-19:47
19:48-19:50
19:51-19:53
ALT km
20
15
10
5
0
19:36
19:45
19:54
TIME
2 GOES-8 VIS 3 JUL 02 19:45 Z NASA LARC •W/E SITES


Radar Reflectivity (dbz) 23z - 7/03/02 Z = 2 km
27.2N
27N
26.8N
26.6N
26.4N
26.2N
26N
25.8N
25.6N
25.4N
82.5W82.2W81.9W81.6W81.3W 81W 80.7W80.4W80.1W79.8W79.5W
55
50
45
40
35
30
25
20
15
10
5
0


AR20020703__CO.WB57
CO Mixing Ratio (ppb)
0
50
100
150
200
250
5.5×10^4
6.0×10^4
6.5×10^4
7.0×10^4
7.5×10^4
8.0×10^4
Elapsed time in UT seconds from 0 hours on the given flight date


0320020703.WB57
800
600
400
200
0
OZONE VOLUME MIXING RATIO IN PARTS PER BILLION BY
5.5×10^4
6.0×10^4
6.5×10^4
7.0×10^4
7.5×10^4
8.0×10^4
ELAPSED TIME IN SEC FROM 0 HOURS UT ON DAY GIVEN BY DATE. THIS TIME IS KEPT BY


NY20020703.WB57
1500
1000
500
0
NO (pptv)
5.5×10^4
6.0×10^4
6.5×10^4
7.0×10^4
7.5×10^4
8.0×10^4
Time (seconds past 0 UT of flight day in line 7)

Summary

- Cloud-resolving MM5 produced generally reasonable convection, although later than observed
- Tracer plumes well-defined at anvil altitudes
- Probability distributions of observations and simulated values generally have similar slope
- Initial conditions for tracers need refinement

Future Plans

- Refine initial conditions for tracers:
  - Use background defined by probability distributions of observations
  - Make use of Twin Otter CO data
  - Run stretched-grid global CTM to generate 3-D initial condition fields
- Rerun tracers with improved MM5 fields
- Run MM5 for two additional cases – July 16, 29
- Possibly run MM5 with 15-km grid to generate initial conditions for 3-D Goddard Cumulus Ensemble Model simulation of C-F events

Future Plans

Interpretation of measurements:

Example 1 – July 23: WB-57 sampled same anvil multiple times to attain time evolution information. How do tracers evolve over time in this anvil and in the model? What do they tell us about transport processes? Develop transport budget for CO.

Example 2 -July 3: CO maxima with "stratospheric" values of O_3, enhanced water vapor and aerosol, but with no NO enhancement. Check convective influence product. Can this plume be linked to biomass burning?

Future Plans

Example 3 – July 16 and 29: Large NO contributions from lightning observed on WB-57 (see poster by B. Ridley et al.).

-- Combination of NLDN and Sferics Array observed lightning data will be input to model to simulate lightning source using several scenarios of NO production per CG flash and per IC flash.

-- Determine best fit scenario through comparisons of model output with observed NO in anvils.

-- Does NO prod. per CG flash = prod. per IC flash?

(see poster by L. Ott)